An Animal Model of Relapse: Resistance to Change and Resurgence in a Symbolic Matching-to-Sample Task.

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by

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Abstract

The present study suggests that relapse can be defined in behavioural terms; relapse is when a subject reverts back to a previously-reinforced behaviour following the disruption of a recently-reinforced behaviour. It is argued that two research areas in the field of the Experimental Analysis of Behaviour are relevant to the study of relapse behaviour. Firstly, Behavioural Momentum Theory addresses the question of what factors determine how disruptable the recently-reinforced behaviour is. Secondly, Resurgence addresses the question of what determines which behaviours increases as the recently-reinforced behaviour decreases following disruption.

Eight experimentally naive pigeons were trained in a matching-to-sample task. Subjects were reinforced for making one response in Condition 1, and a different response in Condition 2. Condition 2 responding was disrupted by three single extinction sessions which occurred at successive points during the condition. Resistance to change was measured as the persistence of responding, consistent with Condition 2 contingencies, during extinction. Resurgence was measured as a shift back to responding which was consistent with Condition 1 contingencies, when reinforcement was withheld in Condition 2.

In Group 1 (Extinction Group), responding consistent with Condition 1 contingencies was specifically extinguished in the process of reinforcing responding in Condition 2. In Group 2 (Response Prevention Group), responding consistent with Condition 1

contingencies was prevented from being reinforced through never presenting choice stimuli in Condition 2 that were consistent with Condition 1 contingencies.

Results indicated that an increase in the duration of reinforcement contingencies did not increase resistance to change. However, subjects in the Extinction Group maintained a higher proportion of correct response during extinction, relative to baseline, compared to subjects in the Response Prevention Group. Difficulties in the measurement of resistance to change, caused by the experimental procedure used, were discussed.

Original analysis of errors made during extinction showed resurgence of responding consistent with Condition 1 contingencies in the Response Prevention Group but not in the Extinction Group. This finding held when a lack of stimulus control was accounted for in the analysis of errors. In the Response Prevention Group, resurgence decreased as the duration of reinforcement contingencies in Condition 2 increased. These findings were shown to be consistent with the response prevention hypothesis of resurgence. The results of the present study were discussed in light of their application to relapse behaviour in humans.

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Introduction

The field of the Experimental Analysis of Behaviour seeks to explain behaviour through its relationship to environmental antecedents and the consequences of reinforcement and punishment. Environmental antecedents signal the presence or absence of reinforcement and/or punishment. In turn, these consequences influence the likelihood that the response will recur, given the same environmental antecedents. One behaviour which can be expressed in terms of behavioural principles is *relapse*. In behavioural terms, a simplification of a relapse scenario would involve a subject who emits an undesirable Behaviour 'A'. The subject has a history of gaining reinforcement for 'A' in the presence of a discriminative stimulus. This discriminative stimulus acts to define the situations in which the behaviour will be likely to occur.

During an intervention process, reinforcement for 'A' is withheld and instead the subject is reinforced for more desirable Behaviour 'B'. Thus, in the presence of the discriminative stimulus, the subject now emits, and is reinforced for, Behaviour 'B'. Relapse occurs when Behaviour 'B' is then challenged or disrupted in some way, and the subject reverts back to Behaviour 'A'. While the term relapse is often associated with addictive behaviours, such as drug or alcohol use, the present research views relapse as a general behavioural response, as defined above.

Within the concept of relapse, two questions arise which are of interest in the Experimental Analysis of Behaviour. First, what are the factors which determine how disruptable the desirable Behaviour 'B' is? Second, what behaviour increases as

Behaviour 'B' decreases following disruption? Two research areas which are relevant to these questions are Behavioural Momentum Theory (Nevin, 1992a) and Resurgence (Epstein, 1985).

While literature dealing with resurgence is relevant to the second question described above, it will be dealt with first in this review. This is due to the relatively small research literature which deals with resurgence compared to that of Behavioural Momentum Theory. The phenomenon of resurgence is that behaviours which were previously reinforced in a given situation tend to recur when a recently-reinforced behaviour is no longer reinforced (Epstein, 1985). Research on resurgence is clearly relevant in addressing the question of what behaviour increases when Behaviour 'B' decreases. Resurgence would suggest that when 'B' is disrupted, rather than behaviour becoming random, or a new response developing, it is likely that a previously-reinforced behaviour will increase. Accordingly, the phenomenon of resurgence in the Experimental Analysis of Behaviour literature may be seen as analogous to relapse as defined by behavioural principles.

The disruptability of behaviour is the domain of Behavioural Momentum Theory. This theory suggests that behaviour can be seen to have the property of momentum (Nevin, Mandell & Atak, 1983). Analogous to the concept of momentum in physics, it is argued that the momentum of a behaviour is determined by its behavioural mass and behavioural velocity. Nevin et al. (1983) proposed that behavioural velocity is analogous to response rate, while behavioural mass is analogous to resistance to change.

Behavioural momentum is best measured as resistance to disruption (Nevin et al., 1983). Typically, experiments measuring resistance to change have involved variable interval (VI) free-operant conditions, in which stable performance is disrupted, usually through extinction or pre-feeding (for example, Nevin, 1974; Nevin et al., 1983; Nevin, Tota, Torquato & Shull, 1990). In these conditions, behavioural momentum is viewed as the resistance of behaviour to disruption relative to baseline. Furthermore, as behavioural momentum does not have an absolute value, the resistance to disruption is measured relative to the resistance to disruption of behaviour in the other conditions of the experiment. Such experiments have yielded a number of findings which build a picture of the nature of behavioural momentum. For example, Nevin (1974) demonstrated that magnitude, delay and frequency of reinforcement increase resistance to change. Furthermore, research by Nevin (1984) and others (see Nevin et al., 1990) demonstrated that response rate and resistance to change are maintained by different determinants.

Thus, the literature relating to Behavioural Momentum Theory addresses the question; what factors determine how disruptable a new behaviour is? The more resistant Behaviour 'B' is to disruption, the more likely that relapse will be avoided or delayed. This means that factors that increase behavioural momentum are likely to make a new behaviour less disruptable and hence, delay relapse.

While resistance to disruption and resurgence have both traditionally been studied using VI free-operant conditions, in the current study they will be measured using a matching-to-sample task. In such a task, each experimental session is made up of a number of discrete trials. On each trial the centre key is illuminated with a sample-

stimulus. This is followed by a number of different choice stimuli on different keys. To obtain a reinforcer, the subject must then peck at the correct choice stimulus depending on what the sample stimulus was.

The current study will consist of two conditions. In Condition 1 subjects will be reinforced for choosing a particular choice stimulus from among a set of stimuli. In Condition 2 subjects will be reinforced for choosing a different choice stimulus. Following a period of reinforcement, responding in Condition 2 will be disrupted by a number of single extinction sessions. Resistance to change will be measure as responding during extinction which is consistent with Condition 2 contingencies. Resurgence will be measured as a shift back to the behaviour which was previously reinforced. In this way, resistance to change and resurgence may be studied simultaneously.

Resurgence

Resurgence refers to the phenomenon of behaviours which were previously reinforced in a given situation tending to recur when a recently-reinforced behaviour is no longer reinforced (Epstein, 1985). Owing to the influence of Freudian theory, this phenomenon was referred to in the early literature as 'regression' (for example Staddon & Simmelhag, 1971; Notterman, 1970). Rawson, Leitenberg, Mulick and Lefebvre (1977) examined the mechanisms responsible for the recovery of 'extinction responding' following the withdrawal of reinforcement for an alternative response. However, not until experiments by Epstein (1983, 1985) was the phenomenon of resurgence explicitly studied.

Epstein's (1983) experiment is typical of those addressing resurgence. In Condition 1, pigeons were reinforced on a VI schedule over 11 sessions for pecking on one of two keys. Condition 2 was an extinction condition lasting for between 1 and 12 one-hour sessions. In Condition 3, an alternative response (for example, wing flaps or turning) was reinforced 20 times. Condition 4 was a test phase in which all reinforcement was withheld. Epstein (1983) found that during extinction (in Condition 4), the frequency of the alternative response decreased in the early part of the session. As the alternative response (wing flapping) decreased, the pigeons began to peck again at the key on which pecks had been previously reinforced.

Early literature explained findings similar to those of Epstein (1983) in terms of a frustration effect, or simple variability in behaviour during extinction (for example, Amsel, 1958; Antonitis, 1951). However, Epstein (1985) argued that because the pecking only occurred on the key for which pecking had previously been reinforced, this ruled out such explanations. Epstein (1985) concluded that these results supported the hypothesis that it was the previously-extinguished behaviour, specifically, that had resurged. In relation to a model of relapse, the phenomenon of resurgence would suggest that when Behaviour 'B' is challenged, previously-reinforced Behaviour 'A' will increase as a result.

Resurgence in Human Subjects

Resurgence has been shown to occur in human subjects with derived relational responses under certain conditions. Derived relational responses refer to those responses that, rather than being directly shaped, have developed through derived connections such as stimulus equivalence, exclusion, and opposition (Wilson &

Hayes, 1996). Wilson and Hayes (1996) trained 25 undergraduate students in a series of these derived relations. In the early phases of the experiment subjects were trained in conditional discrimination through a matching-to-sample task. On each trial subjects were shown a sample stimulus on a computer screen, followed by three choice stimuli. Subjects were required to select the correct choice stimulus depending on what the sample stimulus had been. This training meant that subjects learned three groups of stimulus relations (e.g., A1→B1,C1, and D1; A2→B2,C3 and D3). In preliminary extinction trials subjects made responses that were consistent with their most recent training. Subjects were then trained in a new conditional discrimination task, in which they learned three new groups of stimulus relations (e.g. A1→B3, C2 and D3). Following later training, subjects were exposed to further trials which tested for responding which showed evidence of symmetry and equivalence of the stimulus relations. During these trials, subjects were given specific feedback about their responses. This feedback involved punishment of responses consistent with later training (the word 'wrong' appeared on the screen) and extinction for all other responses. After this feedback, subjects showed a resurgence of responding that was consistent with earlier training. From this research it is clear that findings relating to resurgence found in animal research are supported by similar findings with human subjects.

Mechanisms of Resurgence

Rawson et al. (1977) examined two possible explanations for resurgence of an old response following the withdrawal of reinforcement for a newer alternative response. One explanation for resurgence was termed the response prevention hypothesis. With the introduction of reinforcement for an alternative response, the subject

quickly shifts responding to the alternative response. This means that there is little opportunity to experience the removal of reinforcement for emitting the old response. Thus, the full extinction of the old response is prevented from occurring. When reinforcement for the alternative response is subsequently removed, the original response becomes available again, resulting in a resurgence of this response (Rawson et al., 1977).

Rawson et al. (1977) also described a second possible explanation of resurgence, the discriminative cue hypothesis. This states that the simultaneous extinction of the original response, and introduction of reinforcement for a new alternative response, creates a discriminative cue for the extinction of the original response. When reinforcement for the alternative response is removed, the subject returns to conditions which resemble the original context, causing the original response to recur. Bouton and Swartzentruber supported this explanation of resurgence in their 1991 review of the literature, although they offered no empirical support for discriminative cues hypothesis.

To differentiate these two explanations, Rawson et al. (1977) conducted two experiments using rats as subjects. Experiment 1 consisted of 3 phases. In Phase 1, subjects were reinforced on a VI 30 sec schedule for bar pressing on Lever A. Lever A was the only lever present in the chamber. In Phase 2 subjects were divided into four groups; extinction control, alternative response, response prevention, and forgetting. The extinction control group were placed on extinction for responding on Lever A, and a second Lever B was introduced to the chamber, but responses on this lever were not reinforced. The alternative response group were placed on extinction

for responding on Lever A, and Lever B was introduced to the chamber, with responding on this lever reinforced on a fixed ratio (FR)10 schedule. The response prevention group were placed in the experimental chamber, but no levers were present. Finally, the forgetting group were weighed and handled in the same way as the other groups, but the were not placed in the experimental chamber at all in Phase 2. In Phase 3 of the experiment, all subjects were placed in the experimental chamber. Lever A and B were present, but responding was not reinforced on either lever.

Rawson et al. (1977) found that in Phase 3, responding on Lever A was least in the extinction group, while responding in the other three groups was very similar. There was a similar level of resurgence in the alternative response group as there was in the two groups who were unable to respond on Lever A. This suggests that subjects in the alternative response group did not experience the extinction of responding on Lever A. This result was consistent with the response prevention hypothesis which predicts that the introduction of reinforcement for an alternative response acts to prevent the extinction of original response (Rawson et al.,1977). The response prevention caused by the alternative response had similar effects as true response prevention. However, this does not exclude the influence of discriminative cues in the resurgence of the original response.

Experiment 2 (Rawson et al., 1977) sought to evaluate the influence of discriminative cues in the resurgence of responding. In Phase 1 of the experiment all subjects were reinforced on a VI 30 sec schedule for responding on Lever A. For half the subjects, called the standard groups, Lever B was not present in the chamber.

For the other half of the subjects, called the concurrent groups, Lever B was present in the chamber and responding on this lever was also reinforced on a VI 30sec schedule. In Phase 2, reinforcement for responding on Lever A was extinguished for all subjects. Half the subjects from each group were reinforced for responding on Lever B on a VI 30-sec schedule. For the remaining subjects Lever B was present, but responding on this lever was not reinforced. This division created four groups; standard training extinction, standard training extinction with alternative response, concurrent training extinction, and concurrent training extinction with alternative response. Phase 3 was the same for all subjects, Levers A and B were present, but no reinforcement was given for responding on either lever.

Rawson et al. (1977) argued that groups that had been exposed to reinforcement on Lever B in Phase 1 would be unable to use this as a discriminative cue for Lever A extinction in Phase 2. This would mean that, according to the discriminative cues hypothesis, when reinforcement for Lever B responding is withdrawn in Phase 3, Lever A responding should not resurge. However, results indicated that in Phase 3, the alternative-response groups showed greater resurgence of Lever A responding than the extinction groups, regardless whether they had had experience of reinforcement on Lever B in Phase 1. The combination of results from Experiments 1 and 2 offers strong evidence for a response prevention account of resurgence (Rawson et al., 1977).

While Rawson et al. (1977) supported a response prevention hypothesis of resurgence, Epstein's (1983) experiment created problems for both the response prevention and discriminative cue hypotheses. Both hypotheses predict that subjects

who had a longer period of extinction prior to the introduction of reinforcement for an alternative response, should show less evidence of resurgence when the alternative response is extinguished. If the response prevention hypothesis were correct, a period of extinction prior to the introduction of reinforcement for an alternative response would mean that the subject had to experience the extinction schedule. The longer the period prior to the introduction of reinforcement for the alternative response, the more experience of extinction the subject would have.

As outlined above, the discriminative cues hypothesis states that the simultaneous extinction of the original response, and the introduction of reinforcement for a new alternative response creates a discriminative cue for the extinction of the original response. However, if the subject experienced the extinction of the original response for a period without the introduction of the alternative response then the strength of this cue would be weakened. The longer the period prior to the introduction of reinforcement for the alternative response, the weaker the discriminative cue would be.

In his experiment described above, Epstein (1983) exposed subjects to different numbers of extinction sessions prior to the reinforcement of an alternative response. The alternative response was then extinguished. For each subject, the number of seconds between the last reinforcer for the alternative response, and the resumption of the original response was recorded. Subjects who had had 11 and 12 sessions of extinction of the original response showed resurgence of that response after 30 and 21 seconds respectively. In comparison, subjects who had only 1 and 2 sessions of extinction of the original response showed resurgence after 40 and 33 seconds

respectively. Epstein's (1983) results indicated that there was no difference in time until resurgence with a longer period of extinction of the original response. Thus, while some evidence has supported the response prevention hypothesis of resurgence, other research has been less definitive. The mechanism which underlies resurgence remains to be established.

Resurgence and Relapse

The resurgence paradigm offers clear parallels to relapse. As stated above, the research relating to the phenomenon of resurgence is relevant to the question; what behaviour increases when Behaviour 'B' is challenged? While reverting back to old Behaviour 'A' when a new Behaviour 'B' is challenged may be seen as a relapse to 'A', it may also be described as a resurgence of Behaviour 'A'. I have suggested that relapse and resurgence can be seen as two different ways of looking at fundamentally the same phenomenon.

One factor which has yet to be addressed in relation to resurgence is the way that reinforcement for the previously-reinforced response is withheld when the subject is being reinforced for a new response. Two possible procedures for withholding reinforcement are response prevention[1] and extinction. In response prevention, while the new response is being reinforced, the opportunity for the subject to emit the old response is removed. In contrast, in extinction procedures, an old response can still be made while a new response is being reinforced, but no reinforcement is given for the old response. It is suggested here that the procedure used to withhold

[1] Rawson et al. (1977) used the term 'response prevention' to describe a possible mechanism underlying resurgence, specifically, through the introduction of an alternative response, the subject is prevented from experiencing the non-reinforcement of the original response. The present study uses this term to describe a behavioural technique used to shift responding from one response to another.

reinforcement for an old response will affect the likelihood that the response will resurge when a new response is challenged. Further factors which may influence the likelihood of resurgence occurring are the strength of the previously-reinforced behaviour, and the resistance to disruption of the new behaviour. Literature on Behavioural Momentum Theory addresses the persistence of behaviour under disruption.

Behavioural Momentum

Behavioral Momentum Theory is relevant to the study of relapse as the component of behavioural mass addresses the question, what factors determine the disruptability of a behaviour? If Behaviour 'B' has a high resistance to disruption, then relapse to Behaviour 'A' is likely to be delayed or avoided. Research examining resistance to change has consistently found that more generously-reinforced behaviours, whether measured by frequency, magnitude or immediacy of reinforcement, are more resistant to disruption (Nevin, 1974; Shettleworth and Nevin, 1965; Harper and McLean, 1992; Harper, 1996). This finding holds with a large number of different disrupters including pre-feeding, presentation of response-independent food, and extinction (Nevin, 1984; Harper, 1996; Nevin, 1992b).

Behavioural Momentum Theory proposes that behaviour can be seen to have the property of momentum, analogous to the concept of momentum in physics. In physics, the momentum of an object is determined by its velocity and mass. If Object 'A' has a mass of y and a velocity of x, and Object 'B' has a mass of 3y and a velocity of x, then A and B will differ in their momentum. This difference is most

clearly illustrated in conditions in which an external force is set up to oppose motion. Given an opposing force of equal magnitude to Objects A and B, the effect on B will be less than that on A. While the velocity of the two objects is equal, B has much greater mass, and thus, greater momentum. In physical science the change in the velocity of an object is proportional to the force placed against it, that is:

$$F = m.\Delta v \quad \text{or} \quad \Delta v = F/m \qquad (1)$$

where F is the opposing force, m is mass and v is velocity.

In adapting this concept from physical to behavioural science, it is argued that velocity is analogous to response rate, while mass is analogous to resistance to change. That is, behavioural momentum is determined by behavioural velocity (response rate) and behavioural mass (resistance to change) (Nevin, Mandell & Atak, 1983). Similar to physics, behavioural momentum is best measured when an external force is set up to oppose a response. Equation 1, when adapted to a more general form, becomes:

$$\Delta B = f\left(\frac{x}{m}\right) \qquad (2)$$

where x is the value of a particular external variable or disrupter force, m is the behavioural mass (resistance to change), and B is the behavioural velocity (response rate). Behavioural momentum is indicated by the extent of change in responding given a particular disrupter x, that is, resistance to change.

$$m = x/\Delta B \qquad (3)$$

Because behavioural mass has no absolute value, it is necessary that it be expressed in the same dimension as the disrupter variable. To accommodate this, resistance to change of one response is measured relative to another response when identical disrupting forces are applied to both. In this way, Equation 3 becomes:

$$\frac{m_1}{m_2} = \frac{x/\Delta B_1}{x/\Delta B_2} = \frac{\Delta B_2}{\Delta B_1} \qquad (4)$$

where behavioural mass is expressed as a relative (dimensionless) term, and subscripts 1 and 2 refer to responses 1 and 2 respectively.

An example of a typical resistance to change experiment is that of Nevin et al., (1983). Nevin et al. (1983) used a two component multiple VI VI schedule. The centre key was illuminated green in Component 1 and red in Component 2. Components alternated throughout the 50 minute session for periods of one minute each, with dark-key periods between components. While the reinforcement rates were altered in various conditions, the reinforcement rate in red was always higher than in green. In order to test resistance to change, a variable time (VT) schedule ran in dark key periods to provide response independent food, and this disrupted responding in both components. After baseline response rates were restored subsequent to the removal of the VT schedule, responding was disrupted again with seven consecutive sessions of extinction. Nevin et al. (1983) found that although baseline response rates in the two components were approximately equal, the

component with the greater reinforcement had greater resistance to disruption.

Response Rate and Resistance to Change

In developing a model of behavioral momentum it is important to establish that the two elements of the momentum model, response rate and resistance to change, are in fact separate measures. This means that they are independent aspects of behaviour.

While the independence of resistance to change and response rate was first inferred through the combination of findings from Fath, Fields, Mallot, and Grosset (1983), and Nevin, Mandell, and Atak (1983), the first direct evidence was offered by two experiments conducted by Nevin, Tota, Torquato, and Shull (1990). Nevin et al. (1990, Expt 1) established two components which both operated under the same VI schedule. However, unlike Component 1, Component 2 also had a VT schedule superimposed over the VI schedule. This meant that subjects received greater reinforcement in Component 2, with a proportion of this reinforcement being independent of responding. Response-independent reinforcement acted to degrade the response-reinforcer contingency. Results indicated that responding was greater in Component 1, in which there was a strong response-reinforcer contingency. However, when extinction and pre-feeding were introduced, responding in Component 2 was more resistant to these disrupters (Nevin et al., 1990).

In Experiment 2 (Nevin et al.,1990), Component 1 offered VI reinforcement on the right key. Component 2 operated under the same VI schedule on the right key, but alternative reinforcement was also available under a separate VI schedule on the left key. Given the introduction of the second VI schedule, the total amount of

reinforcement in Component 2 was greater than that of Component 1. Despite greater baseline responding on the right key in Component 1, responding on that key in Component 2 was more resistant to extinction and satiation (through pre-feeding). Thus, as in Experiment 1, alternative reinforcement decreased the response rate while increasing resistance to change. These results clearly indicated that response rate and resistance to change are independent aspects of behaviour.

In relation to a model of relapse behaviour, establishing the independence of response rate and resistance to change is fundamental. In a therapeutic situation, the goal is often to reduce or increase the rate of a target behaviour. However, as discussed below (see section on Pavlovian and Operant contingencies) there is evidence that response rate and resistance to change are largely controlled by different contingencies. This means that a behaviour could occur at a high rate, and yet be easily disrupted. Similarly, a behaviour may occur at a low rate while being highly resistant to change. This means that in a therapeutic situation it is not sufficient to simply increase or decrease the rate at which a behaviour occurs. To strengthen or remove a particular behaviour, it is necessary to increase or decrease respectively, the behaviour's resistance to change.

Disrupters

The measurement of resistance to change necessitates the disruption of a response. Early experiments (e.g. Nevin, 1974) largely focused on extinction and response-independent food to disrupt responding. However, as the research literature dealing with resistance to change has grown, other forms of disruption, such as pre-feeding and pharmacological agents, have been used. The number and diversity of

disrupters, listed below, serves to illustrate the generality of the principles of Behavioural Momentum Theory.

Despite the possibility of using different forms of disruption, the majority of resistance to change research still uses extinction to disrupt responding. Similarly, extinction is also the manipulation used in resurgence research. The use of extinction as a manipulation in both resistance to change and resurgence, establishes the potential for resurgence and resistance to change to be measured concurrently. Furthermore, factors which disrupt responding, allowing a measure of resistance to change, are also likely to lead to relapse.

Pre-Feeding

Pre-feeding involves feeding subjects a percentage of their body weight in the home cage just prior to beginning an experimental session. This acts to satiate subjects to the food reinforcer, and as a result, devalue its reinforcing properties. Under these conditions, responding which is less affected by pre-feeding is argued to be more resistant to change. A number of studies looking at behavioural momentum have successfully used pre-feeding to disrupt responding, with the component with the more generously reinforcement having greater resistant to change (for example, Nevin, 1984; Nevin, 1992b; Nevin & Grace, 1999).

Response-Independent Food

While pre-feeding satiates the subject to reinforcement, response-independent food acts to weaken the response-reinforcer contingency. Response-independent food can be given during black-out periods between components, or through superimposing a

VT schedule over the existing schedule. Harper (1996) sought to isolate the effects of duration and rate of response independent food on the relative resistance to change of two responses. A multiple schedule was established in which both components operated under a VI 120 sec schedule of reinforcement. Component 1 gave reinforcement for 2 seconds, while Component 2 gave reinforcement for 6 seconds. Based on the findings of Nevin (1974, Expt 3) and Harper and McLean (1992), Component 2 should have greater resistance to change. To disrupt responding, Harper (1996) arranged various rates and durations of response-independent food using VT schedules that operated during dark-key periods interposed between components.

Harper (1996) found that responding in both components reduced with the introduction of response-independent food. This reduction was greatest in the component with the smaller magnitude of reinforcement. Decreases in response rate in both conditions became larger as the magnitude of the response-independent food increased. Harper (1996) concluded that the ratio of resistance to change between Components 1 and 2 remained relatively constant, irrespective of the rate or magnitude of response independent food available. This indicated that response independent food offers a valid way of disrupting responding in a behavioural momentum paradigm.

Extinction

Extinction refers to the removal of all reinforcement for a previously-reinforced response. A greater relative number of responses, or a slower relative rate of decrease in response rate during extinction indicates greater resistance to change

(Nevin & Grace, 2000). Extinction has been used widely as an effective disrupter in resistance to change experiments (see Nevin, 1974, Expt 2; Nevin, 1992b; Nevin et al., 1983; Nevin et al., 1990). It has been argued that there are problems in using extinction as a disrupter when measuring resistance to change (see Harper & McLean 1992; Harper 1996; Nevin and Grace, 2000). This argument is considered below (see section on Partial Reinforcement Extinction Effect), however, the majority of data using extinction as a disrupter is consistent with Behavioural Momentum Theory. That is, the majority of studies have found that more generously reinforced responding is more resistant to extinction.

As well as being a valid form of response disruption in resistance to change research, extinction is also the manipulation used in the study of resurgence. When reinforcement for a new alternative response is withdrawn, there is a resurgence of a previously-reinforced response. This means that the use of extinction as a manipulation of responding potentially allows for the measurement of resistance to change, while concurrently establishing a context in which resurgence of an old response may occur.

Conditioned Suppression

One of the earliest forms of response disruption to obtain a measure of response 'strength' was the use of conditioned suppression (for example, Blackman, 1968). A measurement of conditioned suppression initially involves Pavlovian conditioning of a fear response. An unconditioned stimulus (UCS), such as an electric shock produces an unconditioned response (UCR) of 'fear' illustrated by avoidance behavior. When a neutral stimulus, such as the sounding of a tone is repeatedly

paired with the UCS, in time the tone also comes to elicit the same response (conditioned response (CR)). The tone then becomes the conditioned stimulus (CS). Once this conditioning has occurred, the subject is then placed in a particular schedule of reinforcement. After a baseline response rate is obtained, the CS is presented while the subject is responding on the baseline schedule. Because the CS has come to elicit the same response (fear) as the UCS, the subject is likely to display this fear by a suppression of responding, that is, conditioned suppression. Blackman (1968) suggested a response that has greater 'strength' will show less conditioned suppression with the introduction of the CS. Subjects showed the least conditioned suppression in the most generously reinforced component (Blackman, 1965).

Pharmacological Disrupters

Given that the introduction of pharmacological agents have been shown to affect response rates (relative to baseline), Cohen (1986) attempted to determine if such agents could be used as disrupters in a resistance to change context. Using rats operating under various reinforcement schedules, Cohen (1986) used d-amphetamine sulfate, sodium pentobarbital, haloperidol and cholecystokinin-octapeptide to disrupt responding. Nevin, Mandell and Yarensky (1981) had previously found that responding in the initial component of a chained random interval (RI) 40 RI 40 schedule was less resistant to change from satiation and alternative reinforcement than the terminal component. Using pharmacological agents, Cohen (1986) replicated Nevin et al.'s (1981) experiment, but failed to find evidence of consistent effects when pharmacological disrupters were used.

In a second experiment, Cohen (1986) reinforced rats on a multiple fixed interval

(FI) 30 FI 120 schedule. Extinction tests showed clear evidence of greater resistance to change in the component with the greater reinforcement, however pharmacological disrupters failed to give similar results. While the injection of drugs did reduce responding, it did so uniformly across the two components. Cohen (1986) proposed that pharmacological agents are not suitable for use as disrupters in a resistance to change context. More recent research by Harper (1999a) has questioned the conclusion drawn from Cohen's (1986) results.

Harper (1999a) argued that due to a lack of control of the response-reinforcer and stimulus-reinforcer contingencies, Cohen (1986) failed to establish whether greater resistance to change was dependent on reinforcement or response rate in baseline. In contrast to Cohen's (1986) experiment, Harper (1999a) used an experimental design based on Nevin et al. (1992, Expt 1, described above) using haloperidol and clozapine as disrupters. Harper's (1999a) results indicated that both haloperidol and clozapine disrupted responding more in the component which was associated with the least overall reinforcement. This result is consistent with the findings reported by Nevin et al., (1990) using pre-feeding. More recently, Harper (1999b) has found similar results using quinpirole and fluoxetine as disrupters.

While it is clear that certain drugs may disrupt responding, the use of some drugs in a resistance to change context may be complicated by other effects of the drug. Harper (1999b) found that d-amphetamine did not disrupt responding in a manner consistent with resistance to change literature. He argued that the use of d-amphetamine in this context was confounded by the way the drug impaired the subjects ability to distinguish stimuli and as a result, interfered with the stimulus-reinforcer

contingencies established across levers (Harper, 1999b). Thus, certain drugs can act as a valid disrupter on a resistance to change context, except when those drugs are administered at a dose which impedes the subjects ability to distinguish stimuli or make a physical response. In such cases the drug still disrupts responding, but does so uniformly across components (Harper, 1999a, 1999b).

Summary

There is considerable evidence that factors such as response-independent food, extinction, pre-feeding, conditioned suppression, and in some cases pharmacological agents are valid mechanisms by which to disrupt responding. That the findings of resistance to change research hold under such varied forms of disruption strengthens the generality of the principles which underlie Behavioural Momentum Theory. Given that research examining resurgence and resistance to change both manipulate responding through extinction, this allows for the potential to study these two areas of behaviour concurrently. Moreover, the view taken in present research is that the more resistant a behaviour is to disruption, the more likely that relapse will be delayed or avoided. This means that factors which disrupt responding in a resistance to change context will also affect relapse, as defined in behavioural terms.

Factors Affecting Resistance to Change

While there has been much research to determine which factors increase response rate (for example see Herrnstein, 1970), until recent years there has been limited research dealing with resistance to change. Given that resistance to change has been shown to be independent of response rate, it is important to establish what factors act to increase the resistance to disruption of a response. Evidence presented below

indicates that the more generously reinforced a response (whether defined by frequency, magnitude or immediacy of reinforcement), the greater its resistance to change. The view taken in the present research is that factors which increase resistance to disruption should also prevent or delay relapse.

Frequency of Reinforcement

The frequency of reinforcement is the number of times within a session that a reinforcer is given. In a VI schedule, this means that the shorter the average interval between available reinforcers, the greater the frequency of reinforcement. Experiment 1 of Nevin's (1974) experiments varied the frequency of reinforcement in a multiple VI VI schedule. When responding was disrupted using response-independent food (Nevin, 1974, Expt 1) and extinction (Nevin, 1974, Expt 2) Nevin (1974) found that the component with a higher rate of reinforcement had greater resistance to change. These findings have been supported by a number of other experiments which included pre-feeding and conditioned suppression as a form of disruption (Carlton, 1961; Lyon, 1963; Blackman, 1968; Nevin et al., 1983).

Magnitude of Reinforcer

The magnitude of a reinforcer refers to its size. In research using pigeons as subjects, magnitude is usually varied through different durations of access to the grain hopper during reinforcement. Experiment 3 of Nevin's 1974 experiments established a two-key multiple schedule in which the both keys operated under equal VI schedules. The left key (red) gave 7.5 sec access to the hopper, while the right key (green) gave only 2.5 sec access to the hopper. This meant that the two components gave equal rates of reinforcement, but the reinforcers differed in their magnitude.

While baseline response rates differed slightly for the two subjects used, response-independent food consistently acted to reduce relative responding to a greater extent in the green component compared to the red component. Nevin (1974) concluded that the greater the magnitude of reinforcement the greater the resistance to change. This finding was supported by similar experiments conducted by Harper and McLean (1992, Expt 1), Harper (1996) and research by Shettleworth and Nevin (1965) which used extinction as a disrupter.

As an interesting extension to this experiment, Nevin (1974) compared the effect of different response rates in combination with different magnitudes. With the magnitudes as described above, Nevin (1974) compared the effect of VI 1-min schedules with VI 3-min schedules. While the influence of the different reinforcer magnitudes remained, results indicated that the responding maintained by a VI 3-min schedule was more sharply reduced by response independent reinforcement than responding maintained by a VI 1-min schedule.

Delay of Reinforcement

Delay of reinforcement relates to the time between the subject emitting the response (for example, a key peck) and the delivery of the reinforcer. In Experiment 4 of his 1974 paper, Nevin varied the delays to reinforcement in a multiple schedule experimental design. While baseline responding appeared to be relatively insensitive to differences in delay, this was not the case when behaviour was disrupted. When response-independent food was introduced, responding was more resistant to this disruption in the component with the least delay to reinforcement (Nevin, 1974, Expt 1). As the difference in the delays for the two components was increased, the

difference in effect on response rate became more pronounced. Similarly, relative response rates in extinction were consistently lower in the component with the greater delay. From these results it is possible to conclude that the more immediate the reinforcement the greater the resistance to change.

Summary

There is clear evidence that a more generously-reinforced response, whether determined by frequency, magnitude, or immediacy of reinforcement, is associated with greater resistance to disruption. That this holds under such varied definitions of 'generous' and under so many different disrupter indicates that there is a general behavioural relation between generosity of reinforcement and resistance to change (Mace, 1996). This supports the view taken in the current research that findings from the literature on Behavioural Momentum Theory are relevant to relapse behaviour. Given the evidence described above, it is suggested that preventing or delaying relapse to an old behaviour will be assisted by giving a new behaviour frequent, large and/or immediate reinforcement.

Partial Reinforcement Extinction Effect

While much of the research using extinction is consistent with Behavioural Momentum Theory, there are also some exceptions. The Partial Reinforcement Extinction Effect (PREE) refers to the finding in some literature (for example see Lattal, Reilly and Kohen, 1998) that free-operant behaviour maintained by a schedule of intermittent reinforcement is more resistant to extinction than behaviour maintained by continuous reinforcement (CRF) (Mackintosh, 1974). This finding appears to be inconsistent with the behavioural momentum model which dictates that

more generous reinforcement results in higher resistance to disruption. It has been suggested above that the use of extinction to manipulate responding offers a way to study resurgence and resistance to change concurrently. The PREE would appear to weaken this argument. However, Nevin (1988) and Nevin and Grace (2000) argued that the PREE can be accommodated in Behavioural Momentum Theory through the Generalization Decrement Hypothesis.

Nevin (1988) suggested that the practice of measuring free-operant PREE by the total number of responses in a fixed period of extinction is flawed. He reasoned that interpreting data in this way failed to distinguish initial levels of responding from the rate at which that responding decreased in extinction. Nevin (1988) re-analyzed five studies in which the subjects were trained on a schedule of continuous reinforcement and one or more intermittent schedules with equal numbers of reinforcers. He found that as the number of reinforcers delivered in pre-extinction training increased, the CRF condition became more resistant to extinction compared to the intermittent reinforcement condition. Similarly, Nevin's (1988) examination of data from two studies which used independent groups data, showed that while both studies reported a PREE using simple response totals. However, when the data were re-examined as proportions of response rate in the first session of extinction, responding appeared more persistent after CRF than the VR 3 schedule. Furthermore, this difference increased as the duration of training increased. This finding was replicated, though somewhat less convincingly, in the examination of with-in subject comparisons from the same studies.

The Generalization Decrement Hypothesis

Many authors have attempted to account for the PREE through the concept of a generalization decrement (for example Nevin, 1988; Nevin and Grace, 2000). The Generalization Decrement Hypothesis contends that the presence of reinforcers following a response is a fundamental component of the stimulus situation in baseline. Therefore, the removal of the reinforcement contingencies impacts on the stimulus situation (Nevin, 1988). In comparing a schedule of CRF with intermittent reinforcement the effect of the subsequent removal of reinforcers with extinction is different (Nevin and Grace, 2000). Extinction after CRF has a larger impact, or is 'more noticeable' than extinction after intermittent reinforcement (Nevin et al., 1983). With respect to Behavioral Momentum Theory, the disruptive force applied to behaviour in the two schedules is not equal and therefore confounds measurement of relative resistance to disruption (Harper and McLean, 1992; Harper, 1996). Harper and McLean (1992) proposed that the removal of reinforcement contingencies would impact on the stimulus situation differently depending on what the contingency was. When extinction is used to disrupt responding, the conditions which are supposedly maintaining the behavioural mass of the respective responses are removed in the course of assessing that mass (Harper and McLean 1992). Given these factors it is reasonable to expect that responding should be more greatly effected in extinction after CRF compared to intermittent reinforcement.

Nevin and Grace (2000) argued that despite findings of a PREE in the literature, CRF does in fact result in greater behavioural mass than intermittent reinforcement. Rearranging Equation 3, and expressing ΔB as $\log(B_x/B_o)$,

$$\log(B_x/B_o) = -x/m \qquad (5),$$

(where B_x is the response rate under disruption, B_o is the baseline response rate, x represents the value of the disrupter, and m is the behavioural mass) Nevin and Grace (2000) incorporated the principles of the generalization decrement.

Nevin and Grace (2000) argued the behavioral mass is dependent on reinforcer rate according to a power function, allowing the term m to become r^a, where r is the reinforcer rate during training, and a is the exponent of the function relating m to r. In the resistance to change test, situation change occurs in both components but to a different extent depending on the change in reinforcement rate from baseline to extinction. This means that in extinction, the level of change is equal to the baseline reinforcement rate, as reinforcement moves from baseline level to zero. Taking into account the decremental effect of suspending the contingency of reinforcement (c) and the decremental effect (d) of situation change arising from extinction, the equation becomes

$$\log(B_x/B_o) = -x(c + dr)/r^a \qquad (6)$$

where x represents the time in extinction. Thus, Nevin and Grace (2000) sought to augment the basic momentum model with a term which takes in to account the effectiveness of situation change in extinction (dr).

Summary

While research by Nevin (1988) indicated that in some cases the PREE is removed when data are expressed relative to baseline, this is not always the case. Nevin and Grace (2000) demonstrated that the PREE could be accommodated in Behavioural Momentum Theory through the generalization decrement. Thus, while extinction affects different stimulus situations differently, this can be accommodated by taking into account the effectiveness of situation change in extinction. This confirms that extinction is a valid manipulation with which to disrupt responding when measuring resistance to change.

Pavlovian and Operant Contingencies

In the preparations used to study resistance to change both Operant and Pavlovian contingencies exist. It is important to determine the relative influence of these contingencies as this has implications for how to increase or decrease resistance to change. The research detailed below indicated that while response rate is largely determined by Operant contingencies, resistance to change is largely determined by Pavlovian contingencies (Nevin 1984; Nevin et al. 1990). It is of interest that much of the research cited below is also relevant in establishing the independence of response rate and resistance to change. This is because the independence of response rate and resistance to change dictates that they have different determinants.

When a reinforcer is made available to a subject only after that subject has emitted a particular response, this is referred to as a response-reinforcer, or Operant contingency. The more likely it is that the reinforcer will follow the response, the 'stronger' the Operant contingency is. If the likelihood of reinforcement following

the response is reduced, then the 'strength' of the Operant contingency is also reduced. If the subject obtains additional reinforcement independent of the response, then this too will weaken the Operant contingency.

When a reinforcer is made available to a subject only after the presentation of a particular stimulus, this is referred to as a stimulus-reinforcer, or Pavlovian contingency. The more likely it is that a reinforcer will follow the presentation of the stimulus, the 'stronger' the Pavlovian contingency becomes. The contingency may be degraded or weakened by presentation of reinforcers in the absence of the stimulus.

Nevin, Smith and Roberts (1987, Expt 1) trained pigeons in a multiple chained schedule of reinforcement. While the initial links of both components operated under a VI 180-second schedule, transition to the terminal link was contingent on responding in one component, and was not contingent on responding in the other. Nevin et al. (1987) found that resistance to pre-feeding and extinction tests failed to show a clear difference in the contingent and non-contingent components. That is, relative resistance to change was not consistently higher in the response-contingent condition.

In Experiment 2 Nevin et al. (1987) found that resistance to extinction was greater in the non-contingent component when the terminal link signaled reinforcement than when it signaled extinction. Nevin et al. (1987) argued that this implied that resistance to change is determined, at least in part, by stimulus-reinforcer contingencies. Thus, while contingent reinforcement appeared to increase response

rate, examining Experiments 1 and 2 (Nevin, 1986), there was no evidence that contingent responding increased resistance to change. This result is consistent with the proposition that resistance to change is not determined by response-reinforcer (Operant) contingencies.

Fath et al. (1983) conducted an experiment in which response rate was altered while reinforcement rate remained constant. This was achieved through the use of two different pacing contingencies within a multiple schedule VI 1-min VI 1-min. In Component 1, a VI 1-min schedule was accompanied by a differential reinforcement of high rate (DRH) contingency. Three responses were required within three seconds to have the potential to earn reinforcement. In Component 2, a VI 1-min schedule was accompanied by a differential reinforcement of a low rate (DRL) contingency. This meant that inter-response times (IRTs) had to be between 2.5 and 3.5 seconds long to have the potential to earn reinforcement. This experiment was similar to that published by Nevin (1974), with the difference that Fath et al. (1983) controlled for reinforcement density.

Fath et al.'s (1983) experiment established a situation in which response-reinforcer (Operant) contingencies were different (demonstrated by the different response rates) while stimulus-reinforcer (Pavlovian) contingencies were equal. Under these conditions, Fath et al. (1983) found that the two conditions had equal resistance to change, indicating that resistance to change was influenced by Pavlovian contingencies. This contention was also supported by the findings of Nevin et al. (1990), described previously.

An experiment by Nevin (1984) also supported the contention that resistance to change is determined by Pavlovian contingencies. He used a three key multiple schedule in which each key arranged a successive pair of components. Responding in the first component of each pair was reinforced on a VI 120-second schedule. Each condition was signaled by a different colour key (red, yellow, green). Following presentation of the red key, the second component of the pair operated under a VT 24-sec schedule (with the key coloured white). Following presentation of the yellow key, the second component of the pair operated under a VT 120-sec schedule (blue). Following presentation of the green key, the second component of the pair operated on an extinction schedule (orange). Subjects had one minute of access to the first component schedule, at which point the schedule automatically switched to the second component of the pair. This switch was signaled by the change in key colour. The subject then had one minute's access to this schedule at which point there was a time-out and the sequence started again.

The first component of each pair created an Operant response contingency in that there was a link established between the subject emitting a response and receiving a reinforcer. The one minute period in Component 1, was always directly followed by one minute in Component 2 in which reinforcement was given independent of responding. Thus, the second component of each pair established a Pavlovian stimulus contingency in that there is a link between the presence of a particular stimulus (Component 1) and forthcoming reinforcement (Component 2). Thus, this experimental design established a scenario in which response-reinforcer (Operant) contingencies were the same across all three keys, while the stimulus-reinforcer (Pavlovian) contingencies were different.

Nevin (1984) found that in extinction and pre-feed tests, resistance to change was greatest in Component 1 of the red condition (which had the richest reinforcement in Component 2). This difference cannot be explained by response-reinforcer contingencies which were the same across all three conditions. This supports the proposition that stimulus-reinforcer contingencies are effective in resistance to change. In terms of relapse behaviour this finding has direct implications; to prevent or delay relapse, it is important that alternative behaviour is not generously reinforced in the same general stimulus context as the old behaviour. While reinforcing an alternative behaviour in this way may reduce the response rate of the old behaviour, it is also likely to increase the old behaviour's resistance to change.

Challenges to the Pavlovian Contingency Interpretation

Despite the strong evidence for Pavlovian contingencies determining resistance to change, there have been some challenges to this interpretation. Using rats as subjects, Mauro and Mace (1996) attempted to determine if the effect of Pavlovian contingencies on resistance to change was influenced by the discriminative stimulus modality. Mauro and Mace (1996) trained experimentally naive rats to lever-press for reinforcement on a three component multiple schedule which was similar to that of Nevin et al. (1990 Expt 1). In Components 1 and 2 the right (target) lever had equal contingent reinforcement, but Component 1 had a greater stimulus-reinforcer contingency, because it also had a VT schedule superimposed over the VI schedule. In Components 1 and 3, the total reinforcement, and thus stimulus-reinforcer contingencies, were equal. However, Component 3 established a stronger Operant contingency. Components were distinguished by visual and auditory stimuli respectively in different Conditions.

In extinction tests, Mauro and Mace (1996) found that responding in Component 2 was the least resistant to change only when visual stimuli were used to distinguish components. Mauro and Mace (1996) argued that this result indicated that the effect of alternative reinforcement upon resistance to change may depend on the modality of the discriminative stimulus. However, an alternative explanation is that they have failed to establish discriminative stimuli in the auditory stimulus component. In examining the baseline relative response rates in Components 2 and 3, there was little evidence of a distinction between the components with auditory stimuli. Given that subjects failed to distinguish between the different components in the auditory conditions, it is unsurprising that Mauro and Mace (1996) failed to illustrate an effect on resistance to change.

An experiment by Grace, Schwendiman and Nevin (1998) also challenged the Pavlovian contingencies interpretation of resistance to change. They attempted to investigate the effects of unsignaled delay of reinforcement on resistance to change. Their study also included an investigation into the effects of unsignaled delay of reinforcement on preference in concurrent chains. Grace et al.'s (1998) experiment encompassed two phases which took place in the first and second half of each session. Phase 1 examined preference in a concurrent chains experimental design. Phase 2 examined resistance to change (pre-feeding and extinction) in a multiple schedule design.

Phase 2 (the second half of each session) operated under a two component multiple schedule of reinforcement, signaled by the centre key being illuminated either red or

green. Components alternated throughout the second half of the session for periods of one minute each, separated by 30 seconds time out. Both components gave equal rates of reinforcement on separate VI schedules. Responding in Component 1 was reinforced on a VI 40-second schedule, while Component 2 operated on a VI 37-second schedule with a 3-second delay of reinforcement. This delay was not affected by any response made after the reinforced response. After responding stabilised, pre-feeding and extinction tests were used to evaluate the relative resistance to change of the two components.

This experimental design allowed the rate of reinforcement to be held constant in the two components, while instituting an unsignaled delay in one component. This arrangement acted to degrade the response-reinforcer contingency in that component, while maintaining the stimulus-reinforcer contingency. Grace et al. (1998) argued that if resistance to change is determined solely by Pavlovian contingencies, then the presence of an unsignaled delay of reinforcement should have no effect.
In Phase 2, responding in 3 out of 4 subjects was more resistant to pre-feeding in the component with no unsignaled delay, as compared to the component with the delay. These results were supported by extinction tests, in which responding was more resistant to change in the component with no unsignaled delay for 3 out of 4 subjects. Grace et al. (1998) argued that this result gave convincing evidence that resistance to change was not solely determined by Pavlovian stimulus-reinforcer contingencies.

Further evidence for Grace et al.'s (1998) contention that Pavlovian contingencies do not alone determine resistance to change is offered in a similar experiment by Bell (1999). Disruption with pre-feeding and response independent food showed clear

evidence that responding in an unsignaled delay component was consistently less resistant to change than responding in an immediate component. Bell (1999) contended that these results contradicted previous research (Nevin et al. 1990; Nevin et al. 1987) which claimed that resistance to change is determined solely by Pavlovian contingencies.

Summary

Despite several recent studies (i.e. Grace et al., 1998; Bell, 1999) there is considerable evidence that the two components of behavioral momentum, response rate and resistance to change, are largely determined by Operant and Pavlovian contingencies respectively (Nevin 1984; Nevin et al. 1990). In an applied setting, a common therapeutic tool to reduce the rate of an undesirable behaviour is to reinforce a competing alternative response (Nevin and Grace, 2000). However, the evidence presented above indicates that while reinforcing an alternative behaviour may reduce the response rate of the old behaviour, it is also likely to increase its resistance to change. This means that to prevent or delay relapse, alternative behaviour should not be generously reinforced in the same general stimulus context as the old behaviour. Similarly, the resistance to change of a new desirable behaviour may be increased by the simultaneous generous reinforcement for an alternative behaviour.

Resistance to Change in Human Subjects

Nevin (1988) stressed the importance of various experimentally derived facts for intervention with human clients, as have other authors (Plaud & Gaither, 1996; Plaud & Plaud 1998). There has been considerable research (described below)

demonstrating the way in which Behavioural Momentum Theory can be applied to human behaviour. Behavioural Momentum Theory suggests that there is a general behavioural relation between generosity of reinforcement and resistance to change (Mace, 1996). Viewed in this way, Behavioural Momentum Theory offers practical applications for use in the field of applied behaviour change, particularly in clinical interventions, drug addiction and self control (Nevin and Grace, 2000).

Mace, Lalli, Shea, Pinter Lalli, West, Roberts and Nevin (1990) demonstrated that the principles which underlie Behavioural Momentum Theory, hold for human subjects. Mace et al's. (1990) experiment in which two intellectually disabled human subjects participated in a sorting task, was typical of those using Behavioural Momentum Theory in an applied setting. Subjects were reinforced with popcorn or coffee for sorting red and green plastic cutlery. Sorting of one colour was reinforced on a VI 60 second schedule, while sorting of the other colour was reinforced on a VI 240 second schedule.

Following baseline training, resistance to distraction was assessed through the introduction of a videotape of action excerpts from a popular music television programme played at moderate volume on a television set. Mace et al. (1990) found that the sorting of the cutlery associated with a more generous reinforcement schedule was more resistant to distraction than the sorting of cutlery with a less generous reinforcement. This finding was consistent with findings in non-human populations (Mace et al., 1990; Nevin, 1979).

In Experiment 2, sorting of different colour cutlery was reinforced on a VI 60 second schedule (Mace et al., 1990). However, in one component response independent reinforcement was superimposed over the VI schedule through a VT schedule of reinforcement. Consistent with the literature on non-human subjects, sorting behaviour was lower in the VI VT component during baseline, but sorting behaviour in this component was more resistant to disruption. Mace et al.'s (1990) research supports the position that the findings in relation to Behavioural Momentum Theory are not confined to artificial laboratory situations but have practical applications with human subjects.

Mace, Hock, Lalli, West, Belfiore, Pinter and Brown (1988) sought to adapt Behavioural Momentum Theory for use with human subjects with an intellectual disability through the, so-called, 'high-p' procedure. While this procedure is not a strict application of Behavioural Momentum Theory, it was directly inspired by the momentum concept. The 'high-p' procedure produces an increase in compliance with demanding (and normally ineffective) requests by presenting a series of easy or high-probability-of-compliance (high-p) requests before the more demanding one (Nevin 1996). Mace et al. (1998) argued that this procedure indirectly manipulated the rate of reinforcement to create a momentum of compliance which persisted when subjects were asked to perform a low probability behaviour.

Mace et al. (1988) conducted five experiments which evaluated the effectiveness of the high-p procedure in increasing compliance with 'do' and 'don't' commands, and reducing excessive compliance latency. They found that establishing a pattern of compliant responding by the subject, immediately prior to issuing of a low-p request,

resulted in an increase in subject compliance. Furthermore, using a within subject design, Mace et al. (1988) compared the high-p procedure with attention prior to the issue of the low-p request. It was found that it was the series of high-p requests, rather than the presence of attention, that resulted in the increased compliance with low-p requests.

The research presented above demonstrated that, like the phenomenon of resurgence, findings relating to resistance to change with non-human subjects also hold when human subjects are used. If Behavioural Momentum Theory is to be applicable to relapse behaviour, it is vital that results form the resistance to change literature are shown to be supported by research with human subjects.

Summary of Behavioural Momentum Theory

Behavioural Momentum Theory suggests that the momentum of a behaviour is determined by the independent components of response rate and resistance to change. Response rate and resistance to change are largely determined by Operant and Pavlovian contingencies respectively (Nevin et al, 1990). The resistance to change of one behaviour is measured relative to another behaviour when equal disrupting force is applied (Nevin et al., 1983). As discussed above, this disrupter can take many forms, ranging from extinction to pharmacological agents. Furthermore, research has indicated that, frequency, magnitude and immediacy of reinforcement all increase resistance to change (Nevin, 1974). These findings support the argument that Behavioural Momentum Theory describes a general behavioural relation between generosity of reinforcement and resistance to change (Mace, 1996).

Resistance to Change and Relapse

While resurgence provides an explanation of relapse, studies on behavioural momentum relate to the likelihood of relapse occurring. I have suggested that the more resistant Behaviour 'B' is to disruption, the more likely that relapse will be avoided or delayed. Therefore, factors which affect resistance to change also affect relapse. Research has indicated that more generously reinforced behaviours, whether measured by frequency, magnitude or immediacy of reinforcement, are more resistant to disruption (Nevin, 1974; Shettleworth and Nevin, 1965; Harper and McLean, 1992; Harper, 1996). A further way to measure generosity of reinforcement is the duration for which a reinforcement contingency has been in place. I suggest that the length of new Behaviour 'B's reinforcement history will affect its resistance to disruption. That is, the longer the period for which Behaviour 'B' has been reinforced the more resistant it will be to disruption, and in turn, the less likely it will be that the Behaviour 'A' will resurge. Similarly, it may be that the prior strength of Behaviour 'A' will determine whether that response shows resurgence, or where some other behaviour emerges, when 'B' is challenged.

The Present Study

In the review of the literature above, I have taken the view that resistance to change and resurgence are related. Resistance to change describes how likely a response is to withstand disruption, while resurgence describes which response increases as a disrupted response decreases. The parallels of resistance to change and resurgence to relapse behaviour have been clearly demonstrated.

In the present study, resistance to change and resurgence were measured through the use of a matching-to-sample task. In a matching-to-sample task sessions are made up of a number of discrete trials. On each trial the centre key is illuminated with a sample stimulus (for example a red or green light). After a short delay a number of different choice stimuli appear on multiple keys (for example, square, cross, horizontal bar, and vertical bar). To obtain a reinforcer, the subject must then peck at the correct choice stimulus depending on what the sample-stimulus was. That is, the subject must choose the choice stimulus that matches the sample stimulus.

Nevin and Grosch (1990) attempted to measure resistance to change using a matching-to-sample procedure similar to the one described above. They found that accuracy was higher on large-reinforcer trials but that the decrements in accuracy following disruption were equal across large and small reinforcer trials. The present study measured resistance to change by the use of a matching-to-sample task, using extinction as a disrupter. This procedure allowed the occurrence of resurgence to be measured at the same time.

The experiment had two conditions. In Condition 1 subjects learned to respond in a matching-to-sample task in which reinforcement was determined by a particular rule, for example: if the sample stimulus is red, choose the square choice stimulus; if the sample stimulus is green, choose the horizontal bar choice stimulus. Reinforcement in Condition 2 was determined by a different rule. Condition 2 began when each subject had reached a predetermined level of accuracy. To assess resistance to change, three single extinction tests were run during Condition 2. The first test was run when a predetermined level of accuracy was reached. The second and third tests

were run 10 and 30 baseline sessions following the first test. This allowed resistance to change to be measured with different durations of Condition 2 contingencies. The higher the percentage of correct responses (as defined by Condition 2) during extinction, as a proportion of baseline responding, the greater the resistance to change.

In a discrete trials task such as that used in the present study, a decrease in one response must in turn be accompanied by an increase in another response. The presence of resurgence was determined through examining which responses increased when the correct response decreased during extinction. Resurgence was measured as an increase in responding consistent with the Condition 1 reinforcement contingencies during extinction. However, the presentation of the stimulus sets was constructed so that subjects were able to make a novel response during extinction. This meant that a decrease in the correct response did not automatically require an increase in the response which was reinforced during Condition 1.

The present study was carried out with two different groups. In Group 1(Extinction Group), the Condition 1 response was specifically extinguished in the process of reinforcing the Condition 2 response. That is, the choice stimuli which were correct in Condition 1 continued to be presented in Condition 2, but pecks to these stimuli were no longer reinforced. This procedure investigated resistance to change and resurgence of behaviour with extinction. In Group 2 (Response Prevention Group) the Condition 1 response was prevented from being extinguished because the response alternatives that were correct in Condition 1 were not available to the subject in Condition 2. That is, the choice stimuli used in Condition 1 were not used

in Condition 2. This procedure examined resistance to change and resurgence of behaviour following response prevention.

While the mechanism which underlies resurgence is still not clear, research by Rawson et al. (1977), described earlier, supported the response prevention hypothesis. If this explanation was correct, the extinction procedure used in the present study should have a similar effect as true response prevention. This would mean that Groups 1 and 2 should show similar resurgence of responding consistent with Condition 1 contingencies when Condition 2 is disrupted.

Mace et al. (1990) have suggested that Behavioural Momentum Theory describes a general behavioural relation in that, more generously reinforced behaviour is more resistant to disruption. The present study sought to extend the definition of 'generously reinforced' to include the duration for which a reinforcement contingency had been in place. It was hypothesised that the longer the duration of a reinforcement contingency, the more resistant a response would be to disruption.

In these ways, the present study aimed to demonstrate the way in which the behaviour of relapse can be expressed in terms of behavioural principles. This establishes the potential to study relapse behaviour in an experimental analysis setting. The research areas of resistance to change and resurgence have been identified as relevant to relapse as studied in the Experimental Analysis of Behaviour. Factors which affect resistance to change are also likely to affect the persistence of a behaviour under disruption. Similarly, factors which affect resurgence are also likely to affect relapse. The results of the present study were

interpreted and discussed in the context of a model of relapse behaviour.

Method

Two groups of subjects were trained in a matching-to-sample task. For two sample stimuli, subjects were reinforced for making a particular response in Condition 1, and reinforced for a different response in Condition 2. To assess resistance to change, Condition 2 responding was disrupted for each subject by 3 single extinction sessions. The presence of resurgence was evaluated by a procedure which allowed for responding to occur in a manner consistent with the contingencies used in Condition 1 during the extinction sessions. For Group 1 (Extinction Group) the responses consistent with Condition 1 was specifically extinguished in the process of reinforcing the new Condition 2 response. For Group 2 (Response Prevention Group) the choices which were reinforced in Condition 1 were never presented in Condition 2. This meant that responding consistent with Condition 1 was prevented from occurring in Condition 2, and as a result was never specifically extinguished.

Subjects

8 experimentally naive pigeons, were maintained at approximately 80 percent of their free feeding weight. Birds E5, 6, 7, and 8 were used in Group 1. Birds E9, 10, 11, and 12 were used in Group 2.

Apparatus

The experimental chamber used measured 30, by 34, by 33 cm. Three keys were mounted 24 cm above the floor on the right wall (interface panel). One key was placed centrally and the other keys 11.5cm either side of the central key. All keys were used in

the experiment. Active keys had the stimuli projected on them from in-line displays mounted behind each key, and required a force of approximately 0.2N to be operated. Each peck was signaled by a relay click, and the extinguishing of the illuminating light for 50msec. Reinforcement was delivered via a hopper containing wheat, positioned in the center of the interface panel, 10 cm above the floor. The hopper was raised during reinforcement and was lit with a white light.

An IBM-PII compatible computer, with a general purpose interface card, ran a custom programme written in Delhi 4. This programme scheduled and recorded experimental events.

Training

Training was the same for the Extinction Group (Birds E5, 6, 7, and 8) and the Response Prevention Group (Birds E9, 10, 11, and 12). Subjects went through up to six stages of training, which were successive approximations to the final task. Each of the six stages of training are described below. Training sessions were run once a day and were up to an hour in duration for each subject. Subjects were moved from one phase of training to the next when visual inspection of the subjects' performance indicated that the correct response was consistently being made. Table 1 shows the number of sessions spent in each training stage for each subject.

Subjects E5, E6, E9, and E10 were trained in 'exposure red rule' followed by 'exposure green rule'. The order for these two training phases was reversed for subjects E7, E8,

E11, and E12. Subjects E5, E7 and E9 began pecking at the centre key during hopper training and thus, did not go through Centre-key Autoshaping.

Eating from the hopper: Throughout the session the hopper was activated at irregular intervals, allowing the subject access to wheat. Through successive exposure to the hopper the subjects learned to eat from the hopper when activated.

Centre-key Autoshaping: Throughout the session the centre key was illuminated either red or green (alternating on each trial) for 6 seconds. After 6 seconds the center key went dark and the hopper was raised for 4 seconds. Following access to the hopper, all keys went dark and there was a 35 second interval before the next illumination of the centre key. If the subject pecked the centre key when it was illuminated, the key went dark and the hopper was raised for 4 seconds. Subject's remained in this phase of training until they were making regular responses on the centre key.

All-key Autoshaping: The center key was illuminated red or green. The colour on each trial was determined randomly and with equal probability. The subject was required to peck the centre key three times. After the third peck the centre key went dark and one of the two side keys were illuminated.

The particular side key which was illuminated on any trial was determined randomly. If the centre key had been red, the stimulus shown on the side key was a square. If the centre key had been green, the stimulus shown on the side key was a horizontal bar.

If the subject pecked the side key, the key went dark and the hopper was raised for 4 seconds. If the subject did not peck the side key, the key remained illuminated for 6 seconds. After 6 seconds, the side key went dark and the hopper was raised for 4 seconds. Following access to the hopper, all keys went dark for a 6-second inter-trial interval (ITI) before the cycle started again.

Exposure red rule: The centre key, illuminated red, was extinguished when the subject pecked the key three times. When the centre key went dark, a square stimulus and a cross stimulus each appeared on one of the side keys. The placement of the stimuli was determined randomly on each trial. If the subject pecked the square stimulus, all keys went dark and the hopper was raised for 4 seconds. If the subject pecked the cross stimulus, all keys went dark for 4 seconds. The period of non/reinforcement was followed by an ITI of 6 seconds. After the ITI a new trial began.

Exposure green rule: This stage of training was the same as that described in the 'exposure red rule', except that different stimuli were used. The centre key was illuminated green. When the centre key went dark, a horizontal line stimulus and a vertical bar stimulus each appeared on one of the side-keys. If the subject pecked the horizontal bar stimulus, all keys went dark and the hopper was raised for 4 seconds. If the subject pecked the vertical bar stimulus, all keys when dark for 4 seconds.

Exposure combination red-green rules: The centre key was illuminated either red or green. The colour of the centre on any given trial was determined in a quasi-random

manner, so that each subject was exposed to an equal number of red and green trials in a session. If the centre key was green, the procedure followed that detailed above for 'exposure green rule'. If the centre key was red, the procedure followed that detailed above for 'exposure red rule'.

Table 1

Number of sessions spent in each training phase for each subject

Training Phase	E5	E6	E7	E8	E9	E10	E11	E12
Center-key auto	-	3	-	6	-	5	4	3
All-key auto	5	5	7	8	15	2	3	11
Exposure red rule	10	6	2	3	3	5	0	1
Exposure green rule	2	2	9	4	2	2	5	4
Comb-red green	2	3	1	1	3	4	4	3

Group 1 (Extinction Group)

Procedure

Condition 1. For subjects E6 and E7, daily sessions consisted of 80 trials. The sequence of events within a trial was as follows:

1. *Inter-trial interval*: Each trial was preceded by a 6 second inter-trial interval (ITI), during which the house light was on but the keys were dark.

2. *Sample stimulus*: The centre key was illuminated either red or green. These stimuli appeared randomly, and with equal probability. The centre key was extinguished when three pecks had occurred on that key.

3.*Choice stimuli*: Each key was illuminated with one of four possible stimuli; cross (C), square (S), vertical bar (V), horizontal bar (H). On any trial the 'correct' choice

stimulus was presented and two of the three remaining stimuli were selected at random and also presented. The position of the stimuli was determined randomly on each trial, with no stimulus presented twice on the same trial. Reinforcement was defined by the rule: if sample stimulus is red, choose choice-stimulus S; if sample stimulus is green, choose choice-stimulus H. The key lights were extinguished when a single peck occurred on one of the three keys.

4. *Outcome:* Each pigeon earned reinforcement by pecking on the correct key based on the sample stimulus. Reinforcement consisted of access to a grain hopper for 3 seconds. The ITI began after the reinforcement had ended. If an incorrect response was made, the chamber went dark for 3 seconds and the ITI began after this period. This ensured that the total time between trials was independent of whether responses were correct. For each pigeon Condition 1 ran for at least 60 sessions subsequent to the pigeon reaching 85 % correct.

Condition 2. The sequence of events in Condition 2 was the same as in Condition 1, but different choice stimuli were now designated as correct. Reinforcement was defined by the rule: if sample stimulus is red, choose choice-stimulus C; if sample stimulus is green, choose choice-stimulus V. The choice stimuli which were designated as correct in Condition 1 were still present in Condition 2. This meant that learning the correct response in Condition 2 required the extinction of the Condition 1 response.

Extinction Tests. For each subject, the reinforcement schedule for correct responses was disrupted by 3 sessions in which no reinforcement was given for any response. These

extinction sessions were designed to test for resurgence of responding consistent with the contingencies used in Condition 1, as a function of the duration of Condition 2. For each pigeon, the first extinction session was run when their performance indicated that the proportion of correct responses given a red or green choice stimulus was 0.60 or better, for the last five sessions. In these extinction sessions, all three keys were used and were illuminated with three of the four possible choice stimuli chosen at random. Condition 2 was then reinstated for 10 sessions followed by the second extinction session. Condition 2 was reinstated for 20 sessions, followed by the third extinction session. Extinction sessions consisted of 96 trials to allow for the various combinations of stimuli and locations.

For subjects E5 and E8 the procedure was as detailed above except that 6 pecks were required on the sample stimulus and the inter-trial interval was 18 seconds in duration. This was to correct a bias to the centre key which developed during training.

Group 2 (Response Prevention Group)

Procedure

The sequence of events within a trial was the same as that described for Group 1. However, subjects in Group 2 were never shown choice stimuli which had been correct for Condition 1 during Condition 2. This meant that the old response was prevented from being specifically extinguished.

Condition 1.

Choice stimuli: The choice stimuli used were the same as those in Group 1; C,S,V,H. However, only two keys were illuminated on any one trial with the third remaining dark. The two keys used were selected randomly on each trial. As in Group 1, reinforcement was defined by the rule: if sample stimulus is red, choose choice-stimulus S; if sample stimulus is green choose choice-stimulus H. On any trial, if the sample stimulus shown was red, then choice stimuli S and C each appeared randomly on one of the keys; if the sample stimulus was green then choice-stimuli V and H each appeared randomly on one of the keys. The key lights were extinguished when a single peck occurred on one of the two keys.

Outcome: Subjects earned reinforcement by pecking on the correct key based on the sample stimulus. Reinforcement consisted of access to a grain hopper for 3 seconds. The ITI begin after the reinforcement had ended. As in Group 1, if the pigeon pecked at the incorrect key the chamber was darkened for 3 seconds and the ITI began after this period. For each pigeon Condition 1 ran for at least 60 sessions subsequent to the pigeon reaching 85 % correct.

Condition 2. The sequence of events in Condition 2 was the same as in Condition 1. Reinforcement was defined by the rule: if sample stimulus is red choose choice-stimulus C, if sample stimulus is green, choose choice-stimulus H. On any trial, regardless of the sample stimulus shown, choice stimuli C and V each appeared on a randomly chosen key. By presenting the choice stimuli in this way the subject was never able to make a response in Condition 2 which would have been correct for Condition 1. This meant

that the rule consistent with Condition 1 was never specifically extinguished, but rather, Condition 1 behaviour was prevented.

Extinction Tests. For each subject, the reinforcement schedule for correct responses was disrupted by 3 sessions in which no reinforcement was given for any response. In these sessions, all three keys were used and were illuminated with three of the four possible choice stimuli chosen quasi-randomly. This meant that during Extinction session, subjects were able to make a response that had previously been reinforced in Condition 1. As in Group 1, these extinction sessions were designed to test for resurgence of responding consistent with the contingencies used in Condition 1, as a function of the duration of Condition 2. The scheduling of these extinction tests was that same as that detailed for Group 1. Table 2 shows which of the sample stimuli were displayed and the correct response for all the experimental conditions for both Groups 1 and 2.

Table 2

Sample stimuli displayed and correct responses given red or green choice stimuli for experimental conditions in Group 1 and Group 2.

Group 1	Condition 1		Condition 2		Extinction	
Sample stimulus	Choice stimuli shown	Correct	Choice stimuli shown	Correct	Choice stimuli shown	Correct
Red	S+ any 2 of C,V,H	S	C+any 2 of S,V,H	C	Any 3 of S,C,V.H	None
Green	H+ any 2 of S,C,V	H	V+any 2 of S,C,H	V	Any 3 of S,C,V.H	None
Group 2	Condition 1		Condition 2		Extinction	
Sample stimulus	Choice stimuli shown	Correct	Choice stimuli shown	Correct	Choice stimuli shown	Correct
Red	S,C	S	C,V	C	Any 3 of S,C,V.H	None
Green	H,V	H	V,C	V	Any 3 of S,C,V.H	None

Results

Performance on the Matching-to-Sample Task.

The sample stimulus, choice stimuli, and subject response were recorded on each trial for each subject. Table 3 shows the average number of sessions in Condition 1 for Group 1 (Extinction Group) and Group 2 (Response Prevention). The average number of sessions in Condition 2, prior to the first extinction test, and the average proportion of reinforced trials is also shown in Table 3.

Table 3

The average number of sessions in Condition 1, average number of sessions in Condition 2 prior to first extinction, and proportion of reinforced trials in Condition 2 prior to extinction for the Extinction and Response Prevention Groups.

	Extinction Group	Response Prevention Group
Average number of sessions in Condition 1	100.25	83.25
Average number of sessions in Condition 2 prior to first extinction test	20.25	24.5
Average proportion of reinforced trials in Condition 2 prior to the first extinction test	0.52	0.58

As can be seen from Table 3, on average subjects in the Extinction Group (range 95-117 sessions) took longer than subjects in the Response Prevention Group (range 83-84 sessions) to reach the performance criterion in Condition 1. This difference is likely to be a function of the level of difficulty of the tasks for the two different groups. On any given trial, subjects from the Extinction Group were presented with three different choice stimuli from which to choose the correct response. In contrast, subjects in the

Response Prevention Group were only presented with two choice stimuli from which to choose the correct response.

Figure 1 shows the types of errors made by subjects in the Extinction Group over the course of Condition 1. The Response Prevention Group were only able to make one type of error, so Condition 1 errors were not analysed for this group. Errors for the Extinction Group in Condition 1 were categorised as 'opposite errors' and 'other errors'. An 'opposite error' was when the subject pecked at the choice stimulus which was correct in the presence of the opposite sample stimulus. That is, pecking the horizontal bar choice-stimulus when a red sample-stimulus had been shown, or pecking the square choice-stimulus when a green sample-stimulus had been shown. An 'other error' was when the subject made a response that was not correct but was not an 'opposite error'. That is, pecking either the vertical bar choice-stimulus or cross choice-stimulus when the sample-stimulus had been red or green. Figure 1 shows the average number of 'opposite' and 'other' type errors as a proportion of the total errors made for subjects in the Extinction Group during Condition 1.

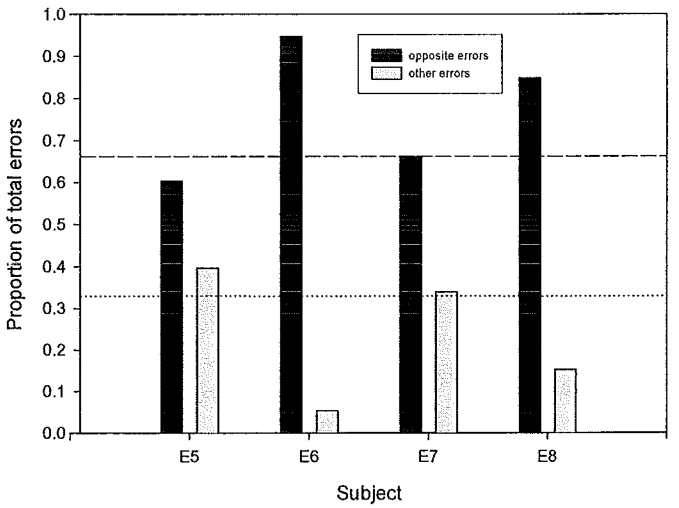

Figure 1. Average number of 'Opposite' and 'Other' errors as a proprotion of total errors in Condition 1 for each subject in the Extinction Group.The dotted and dashed lines show the level at which 'opposite errors' and 'other errors' respectively would occur by chance.

Because there were four stimuli contributing to the 'other' errors and only two stimuli contributing to 'opposite' errors, chance response levels have been marked. The dotted line on Figure 1 shows the level at which 'opposite errors' would occur by chance. The dashed line on Figure 1 shows the level at which 'other errors' would occur by chance. Visual inspection of Figure 1 indicated that 'opposite errors' were made at a higher level than 'other errors' in Condition 1, in that they were generally at or above chance level, where as 'other ' errors were at or above chance level.

As can be seen from Table 3, the average number of sessions in Condition 2 prior to the first extinction test, and the proportion of those trials that were reinforced, appeared to be similar across the two groups. On average, the Response Prevention Group (range 12-32 sessions) took approximately four sessions longer to reach the performance criterion in Condition 2 than did subjects in the Extinction Group (range 15-36 sessions). On average, subjects in the Extinction Group (range 44-60 percent) made a correct response on 52 percent of trials , while subjects in the Response Prevention Group (range 55-61 percent) made a correct response on 58 percent of trials.

Figures 2 and 3 show the proportion of correct responses in each session over the course of Condition 2 for each subject in the Extinction and the Response Prevention Groups respectively. While there were some fluctuations, all subjects in the Extinction Group showed a similar trend; proportion of correct responses increased over the first 12-15 sessions of Condition 2. In contrast, subject in the Response Prevention Group had a higher initial level of correct responses, which increased more gradually over sessions.

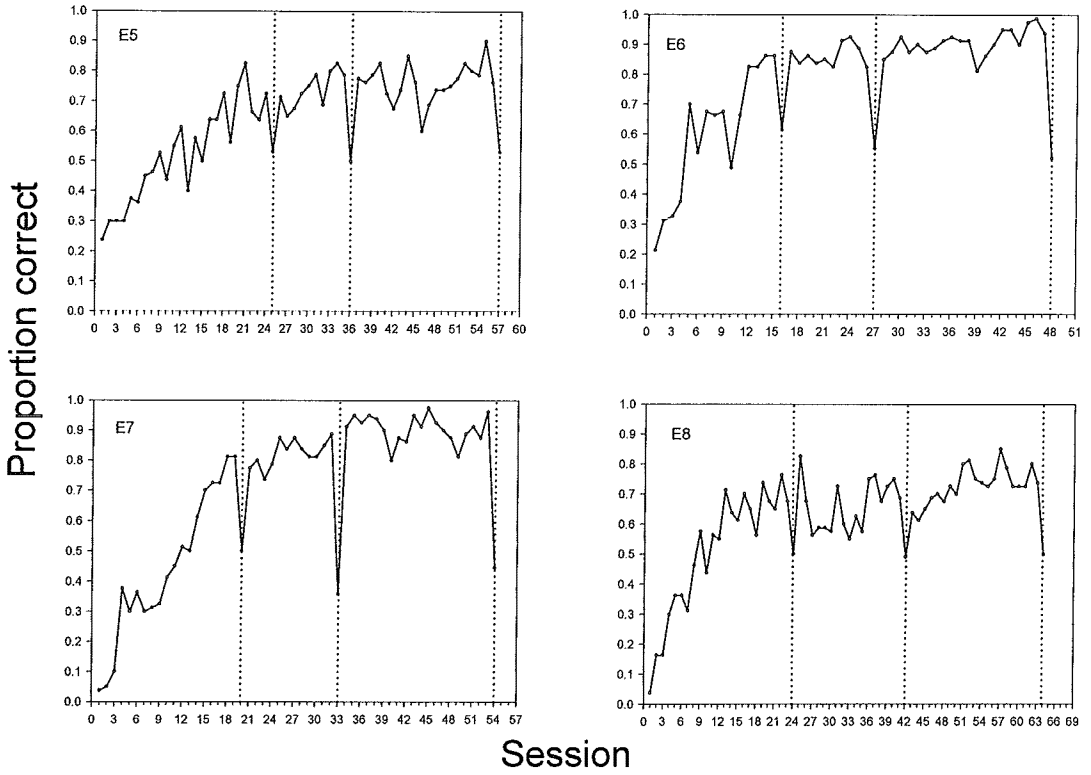

Figure 2. Proportion of correct responses for each subject in the Extinction Group as a function of the number of sessions in Condition 2. The dotted lines mark where the extinction sessions occured for each subject.

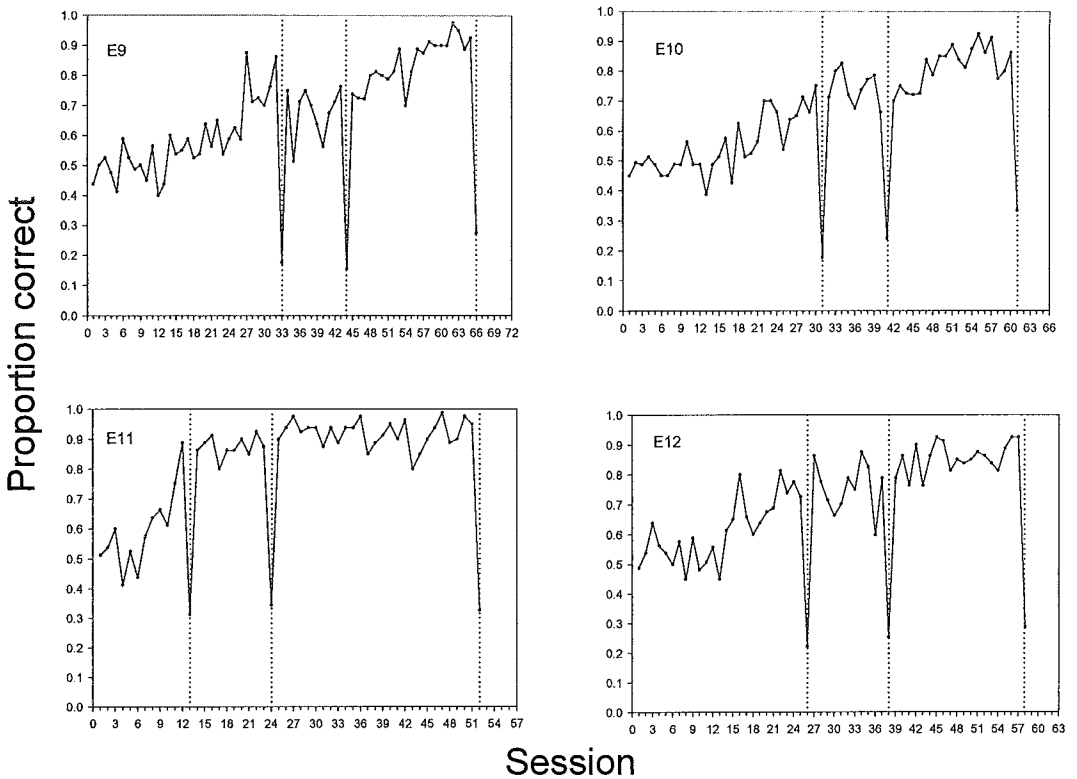

Figure 3. Proportion of correct responses for each subject in the Response Prevention Group as a function of the number of sessions in Condition 2. The dotted lines mark where the extinction sessions occured for each subject.

A decrease in the proportion of correct responses during extinction sessions can been seen for all subjects. This decrease is generally larger for subjects in the Response Prevention Group compared with the Extinction Group.

Figure 4 shows the average proportion of correct responses for the five sessions preceding each extinction test, averaged for the Extinction Group and the Response Prevention Group. Each of the three extinction tests signified a successively longer period for which the Condition 2 contingencies had been in effect. Visual inspection of Figure 4 suggests that both groups showed a slight increase in the proportion of correct responses over Condition 2. However, these changes were small, and the ranges over subjects overlapped. Subjects in both groups were already performing at a high level prior to the first extinction test.

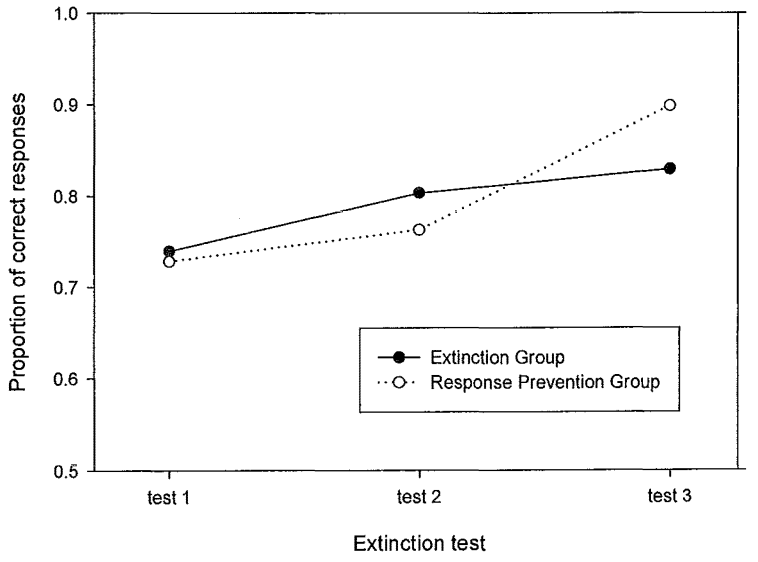

Figure 4. Average proportion of correct responses for the five sessions preceding each extinction test for the Extinction and Response Prevention Groups.

Resistance to Change

Figure 5 shows the proportion of 'correct' responses (according to Condition 2 contingencies) in each extinction test relative to baseline, for each subject. The proportion of correct responses was calculated by dividing the number of responses that were correct (as defined in Condition 2) by the total number of responses made. This number was then divided by the average proportion correct in the five sessions prior to each extinction test to give a proportion of baseline. The left side of Figure 5 shows data from the Extinction Group, while the right side is data from the Response Prevention Group.

Visual inspection of Figure 5 confirms that there was a difference in the degree of disruption of correct responses between the Extinction Group and the Response Prevention Group. Subjects in the Extinction Group had a higher proportion of correct responses (relative to proportion correct in baseline) than subjects in the Response Prevention Group. This difference can be most clearly seen in Figure 6, which plots the average proportion of correct responses in extinction as a proportion of baseline for each group. While the proportion of correct responses during extinction for the Extinction Group is approximately 65 percent of baseline, for the Response Prevention Group it is only around 30 percent of baseline. A higher level of correct responses during extinction indicates that Condition-2 responding by subjects in the Extinction Group was more resistant to disruption than responding by subjects in the Response Prevention Group.

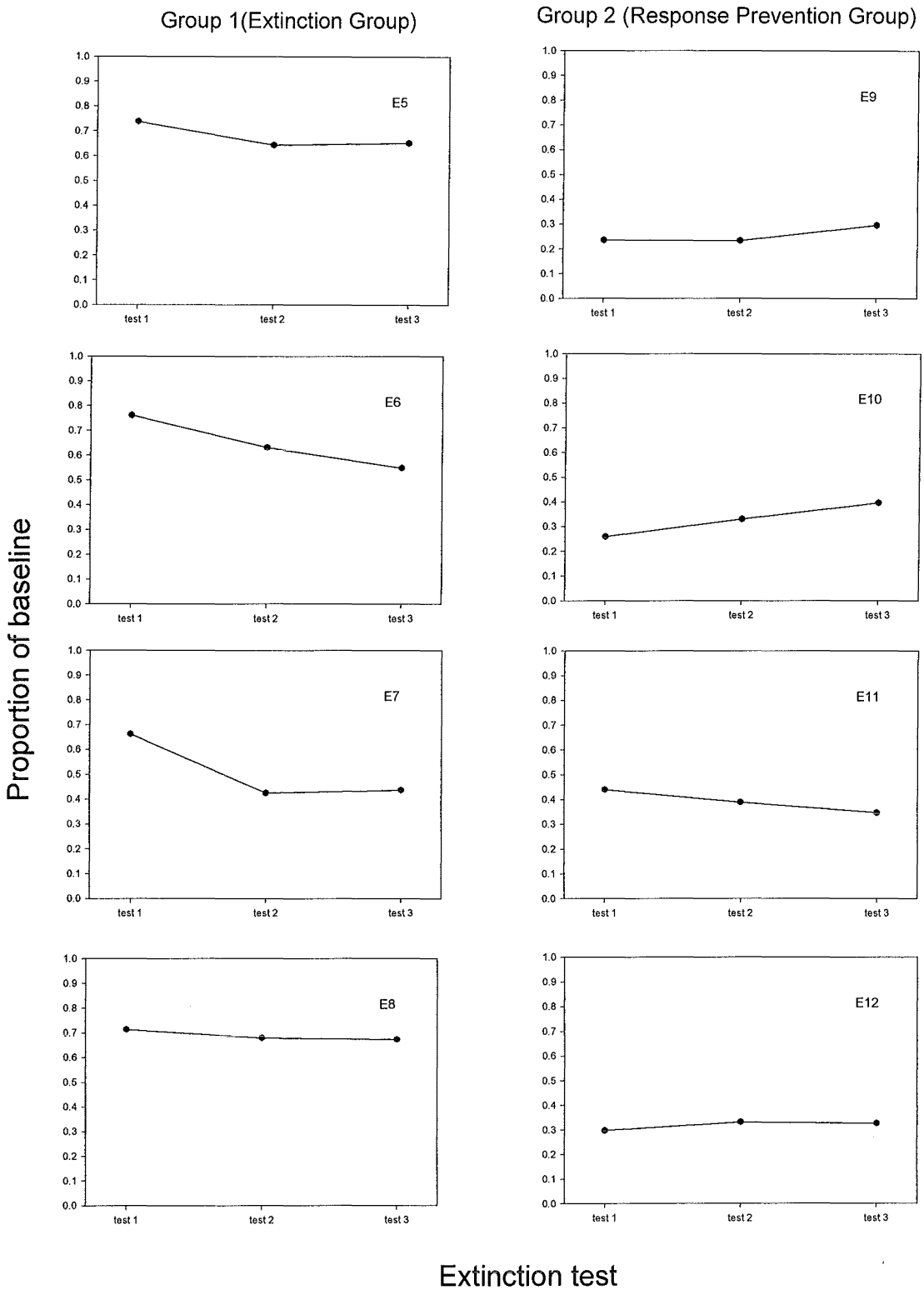

Figure 5. Proportion correct as a proportion of baseline correct, as a function of extinction test 1,2, and 3. The Extinction Group is represented on the left side of the figure. The Response Prevention Group is represented on the right side of the figure.

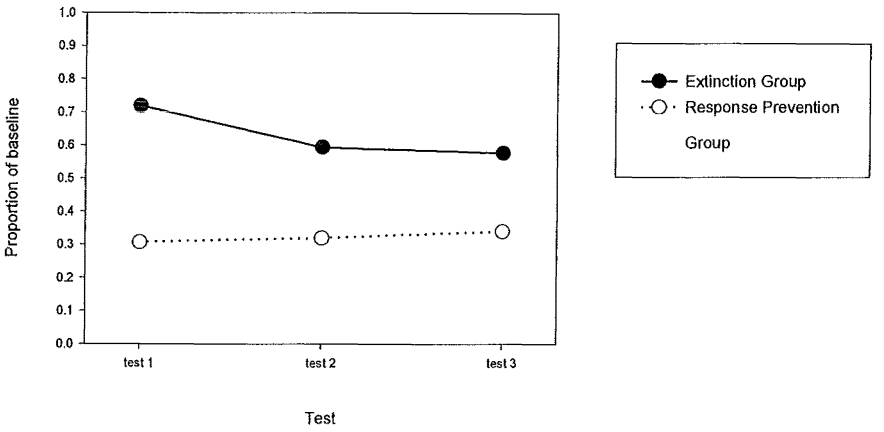

Figure 6. Average proportion correct as a proportion of baseline for the Extinction Group and the Response Prevention Group, as a function of extinction test 1, 2, and 3.

It was hypothesized that the longer the duration for which a response had been reinforced prior to disruption in Condition 2, the more resistant the response would be to that disruption. The results of the present study did not support this hypothesis. In the Extinction Group, all subjects showed a decrease in correct responses over successive extinction tests (Figure 5). For subjects E5 and E8 this decrease was small. Subjects E6 and E7 showed a more substantial change in correct responses over extinction tests, both decreasing by approximately 20 percent. In contrast, subjects in the Response Prevention Group showed no clear pattern. Any change in correct responses over the three extinction sessions were negligible, and the direction of the changes differed among subjects.

Resurgence

Table 4 shows the history and Condition-2 classification of each possible choice-stimulus/sample-stimulus combination. Each combination describes the subject pecking a particular choice stimulus given that a particular sample stimulus was shown.

Table 4

History and Condition-2 classification of each choice stimulus-stimulus/sample-stimulus combination for the Extinction and Response Prevention Groups.

Sample-Stimulus/ choice-stimulus combination	History	Condition 2 classification
Red→ Square (S|R)	Correct in Condition 1	Old correct
Red→ Cross (C|R)	Correct in Condition 2	Correct
Red→ Vertical (V|R)	Never correct, but V/G correct in Condition 2	New opposite
Red→ Horizontal (H|R)	Never correct, but H/G correct in Condition 1	Old opposite
Green→ Square (S|G)	Never correct, but S/R correct in Condition 1	Old opposite
Green→ Cross (C|G)	Never correct, but C/R correct in Condition 2	New opposite
Green→Vertical (V|G)	Correct in Condition 2	Correct
Green→ Horizontal (H|G)	Correct in Condition 1	Old correct

Responses that were not correct for the contingencies in Condition 2 were classified as errors. Errors were divided into three different types: 'old correct', 'old opposite' and 'new opposite'. Table 5 shows the choice-stimulus/sample stimulus-combinations that characterise the three different error types. 'Old correct' were pecks to the choice stimuli which had been correct for each of the red and green sample stimuli in Condition 1. 'Old opposite' were pecks to the choice stimuli which had been correct in the presence of the opposite sample stimulus in Condition 1. 'New opposite' were pecks to the choice

stimuli that were correct for the opposite sample stimulus in Condition 2. During extinction tests, a high proportion of 'old correct' responses would indicate resurgence.

Table 5

Members of Error types

Type of Error	Members
New opposite	V|R, C|G
Old correct	S|R, H|G
Old opposite	H|R, S|G

The proportion of total errors was calculated by dividing the total number of errors in each extinction test into the number of errors in each error type. Figure 7 shows each type of error as a proportion of total errors averaged over the three extinction tests for each subject. The Extinction Group is shown at the top of the figure while the Response Prevention Group is at the bottom of the figure. For both groups, the horizontal dotted line indicates the level at which each type of error would have occurred by chance. All subjects in the Extinction Group consistently favoured the 'new opposite' type error. In contrast there was no consistent preference for one error type for subjects in the Response Prevention Group. However, 'old correct' type errors occurred at or above chance for all subjects in the Response Prevention Group. This finding was also true when errors were examined for each extinction test individually.

Figure 8 shows the same analysis for each extinction test individually. Results from the Extinction Group are shown on the left side of Figure 8, while results from the Response

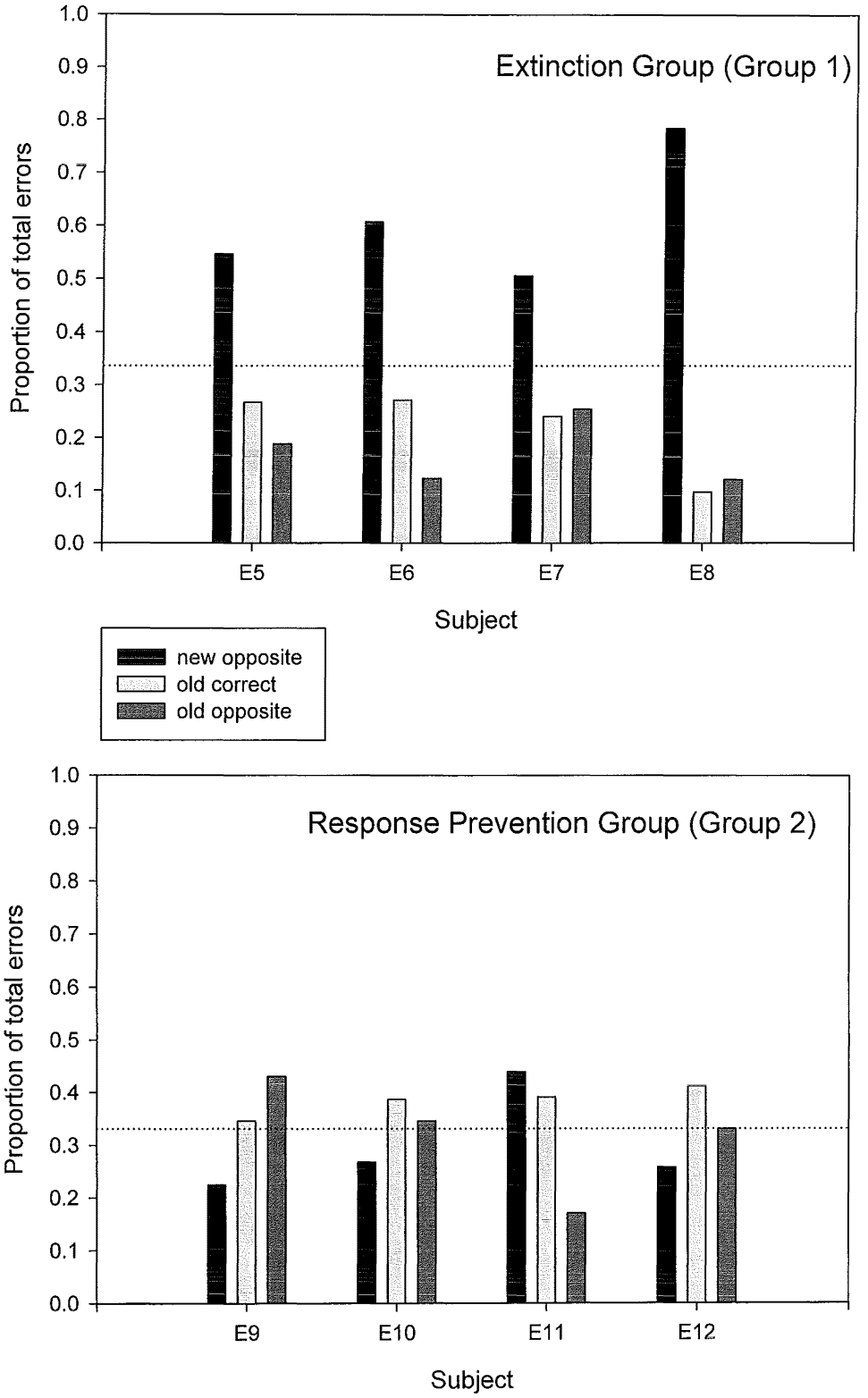

Figure 7. Average number of 'new opposite', 'old correct' and 'old opposite' type errors as a proportion of total errors in the three extinction tests for each subject in the Extinction Group (upper graph) and the Response Prevention Group (lower graph). The dotted lines show the chance level for all error types.

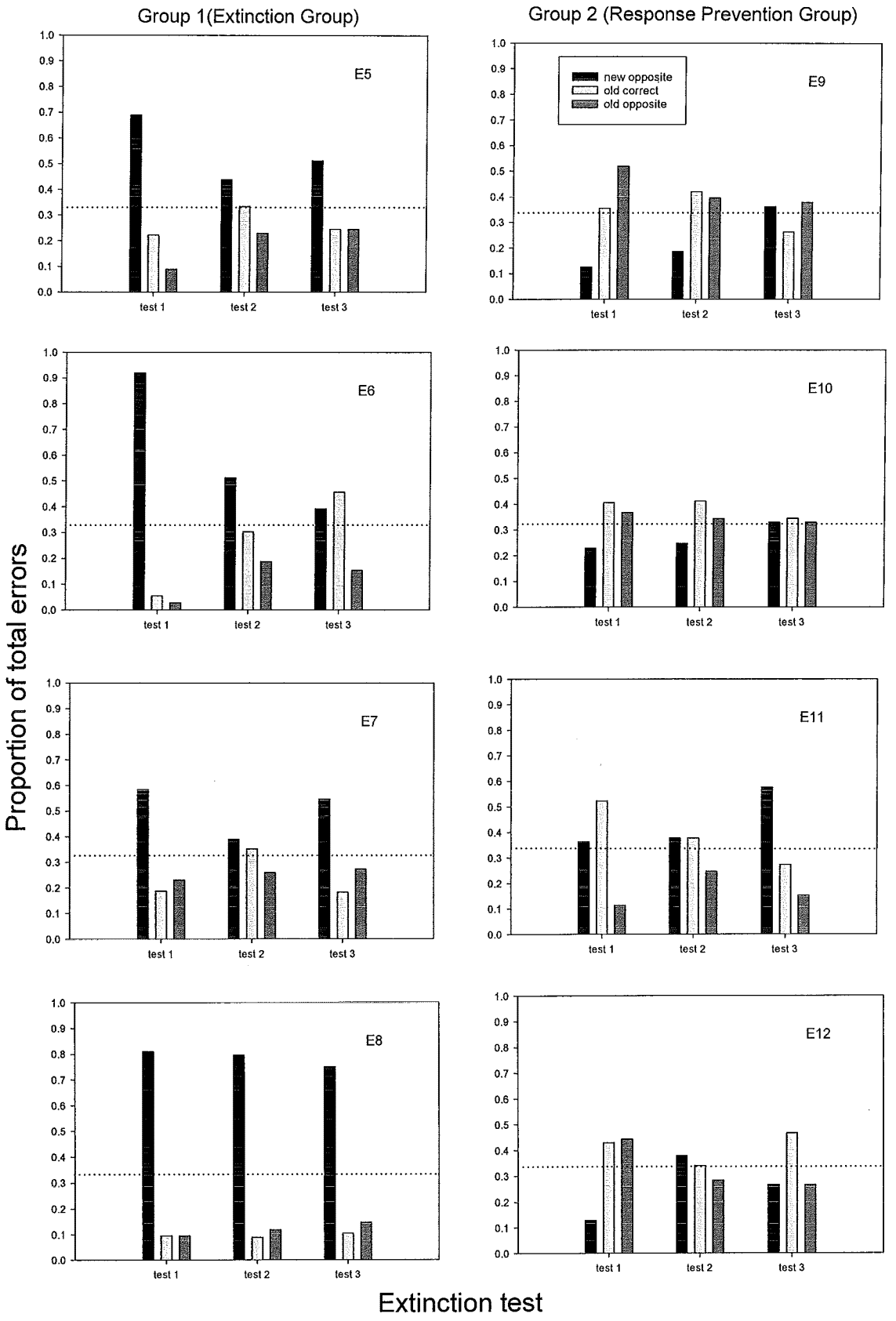

Figure 8. Type of error as a proportion of total errors, as a function of extinction test 1, 2, and 3. The Extinction Group is represented on the left side of the figure. The Response Prevention Group is represented onthe right side of the figure. The dotted lines show the chance level for all error types.

Prevention Group appear on the right. The dotted lines show the chance level for all error types. There was no clear pattern of responding over the course of the three extinction tests for either the Extinction Group or the Response Prevention Group. Visual inspection of Figure 8 indicates that there was a key difference between the two groups in the distribution of errors. In the Response Prevention Group, all errors occurred at a similar frequency. However, 'old correct' type errors occurred at or above chance for each subject in Extinction tests 1 and 2. By the third extinction test 'old correct' type errors were above chance for two out of the four subjects in the Response Prevention Group. A preference for 'old correct' type errors is consistent with resurgence. In contrast, subjects in the Extinction Group all showed a clear preference for a 'new opposite' error. While the 'new opposite' type error remained consistently high for E8, for the remaining subjects this preference reduced in Extinction Test 2 as the 'old correct' error increased. In the third extinction test, preference for 'new opposite' increased again for subjects E5 and E7, but continued to reduce for E6.

As described earlier, Figure 5 showed that the Response Prevention Group showed a decrease in the proportion of correct responses relative to baseline in the three extinction tests. Due to the discrete trials involved in a matching-to-sample task, a decrease in one response must be matched by an increase in a different response. However, while the extinction sessions were the first opportunity the Response Prevention Group subjects had to make the response for which they had been reinforced in Condition 1, Figures 7 and 8 showed that subjects in this group showed only a modest preference for 'old correct' responses.

One explanation for the modest preference for 'old correct' by subjects in the Response Prevention Group is a lack of stimulus control in Condition 1. In Condition 1, the Response Prevention Group were shown either a red or green sample-stimulus, and then had to peck at the correct choice stimulus. However, subjects were never exposed to the correct choice stimulus for the red sample-stimulus in the presence of the green sample stimulus, or vice versa. This meant that the subjects did not need to discriminate between the sample stimuli in order to make a correct response, and either of the two choice stimuli, if seen, were correct.

If subjects in the Response Prevention Group failed to learn to distinguish the two different sample stimuli in Condition 1, this would mean that these subjects could make only two types of errors; 'new opposite' and 'combined old correct'(old correct and old opposite summed). If this was the case then it would be expected that in the extinction tests, 'old correct' and 'old opposite' errors should occur at a similar frequency for subjects in the Response Prevention Group. As can be seen for Figure 8, there is no systematic difference between the level of the 'old correct' and 'old opposite' type errors for subjects in this group across the three extinction tests. Response Prevention Group. This is consistent with the lack of stimulus control hypothesis outlined above. In the remainder of this section , I consider the present data from this perspective.

The lower half of Figure 9 shows type of error (with old correct and old opposite error summed to create a 'combined old correct' category) as a proportion of total errors

averaged over the three extinction tests for each subject in the Response Prevention Group. The dotted horizontal line indicates the level at which 'new opposite' type error would occur by chance. The dashed horizontal line indicates the level at which 'combined old correct' errors would occur by chance. To allow for comparison, the top half of the figure shows the same analysis for the Extinction Group. Averaged over the three extinction tests, three out of four subjects in the Response Prevention Group showed a clear preference for the 'combined old correct' type error. In contrast, all subjects in the Extinction Group show a clear preference for the 'new opposite' type error. Subject E11 in the Response Prevention Group also showed a preference for 'new opposite'.

Figure 10 shows the log ratio of observed proportion of 'combined old correct' type errors, relative to chance in the three extinction tests. The ratio of observed to chance 'combined old correct' errors was calculated by dividing the observed errors by chance level for this error type. The log of this ratio was then calculated. The filled symbols indicate Extinction Group subjects, while the unfilled symbols show subjects in the Response Prevention Group. Values above zero indicate a preference for 'combined old correct', while values below zero indicate a preference for 'new opposite' errors. Thus, resurgence would be indicated by values above zero.

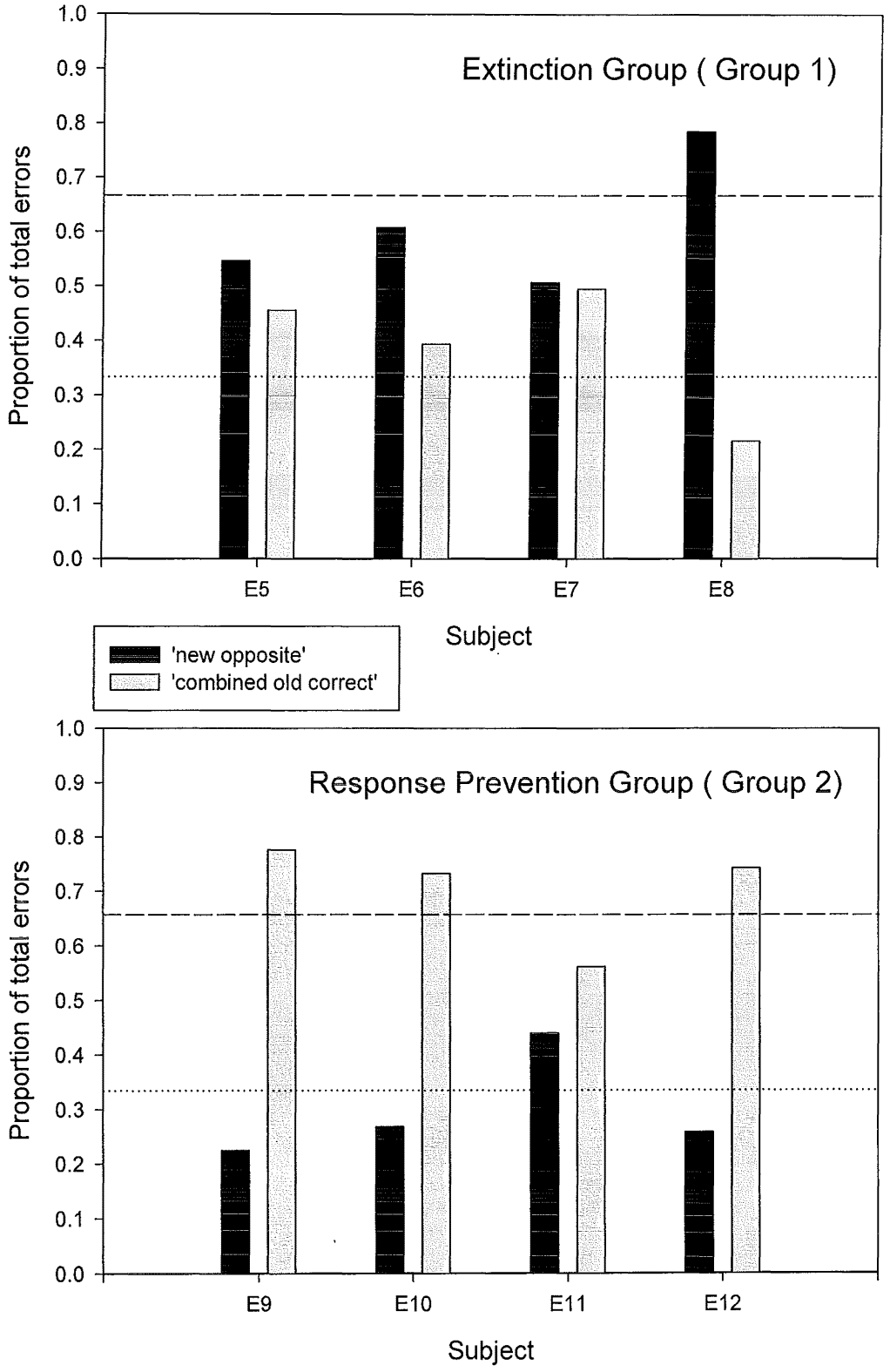

Figure 9. Average number of 'new opposite',and 'combined old correct' type errors as a proportion of total errors in the three extinction tests for each subject in the Extinciton Group (upper) and the Response Prevention Group (lower). The dotted and dashed lines show the level of chance for new opposite and combined old correct type errors respectively.

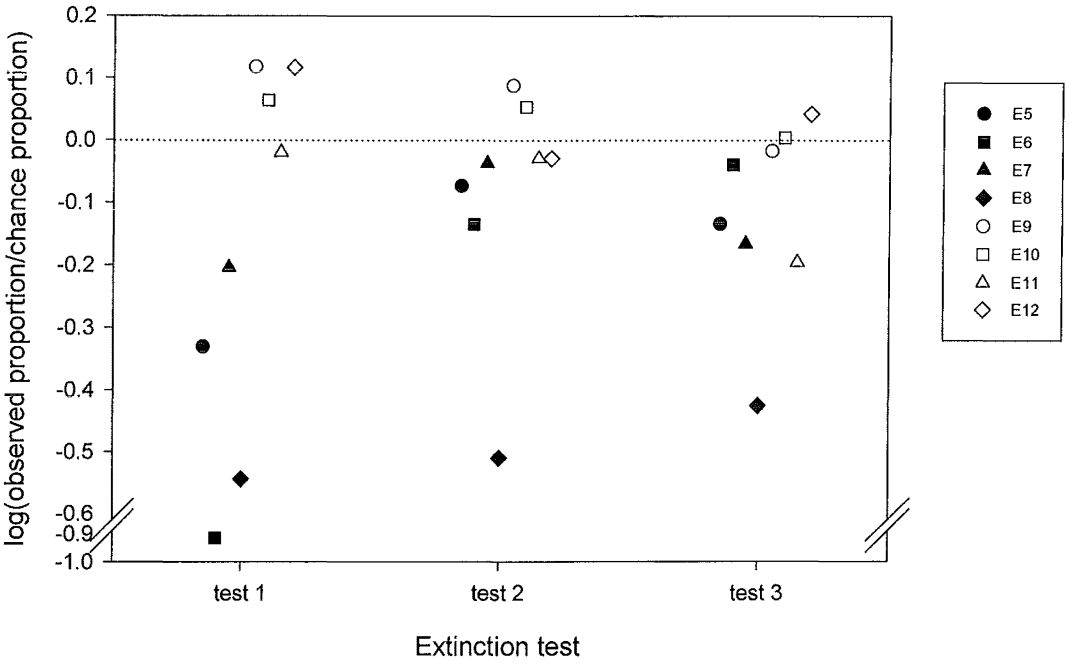

Figure 10. Log ratio of observed proportion of 'combined old correct' relative to chance in Extinction tests 1, 2, and 3, for each subject. The Extinction Group are shown by the filled symbols. The Response Prevention Group is shown by the unfilled symbols.

Visual inspection of Figure 10 shows that three out of the four subjects in the Response Prevention Group showed a similar pattern of responding across the three extinction tests. Subjects E 9 and E10 demonstrated a clear preference for 'combined old correct' in the first extinction test, which gradually reduced over subsequent tests to approximately chance levels on Extinction Test 3. Subject E12 displayed a similar pattern of responding, but with a more pronounced reduction in 'combined old correct' responses during Extinction Test 2. In contrast, subject E11 showed no preference for

either 'combined old correct' or 'new opposite' error in Extinction Tests 1 and 2, but a clear preference for 'new opposite' type error in Extinction Test 3.

All subjects in the Extinction Group showed a clear preference for the 'new opposite' type error (indicated by negative values on Figure 10) over all three extinction tests. While preference for 'new opposite' errors reduced by differing amounts for all subjects over the course of the three extinction tests, it always remained above chance levels.

Resurgence is shown by an increase in a previously-reinforced response when a newly-reinforced response is put into extinction. In the present study there was evidence of resurgence of the 'old correct' type response by subjects in the Response Prevention Group but not in the Extinction Group(Figures 7 and 8). However, the extent of the resurgence was small and variable. It was suggested that this could be accounted for by an absence of stimulus control of the sample stimuli in Condition 1. If the present data are examined from the position that subjects in the Response Prevention Group did not need to learn to differentiate between the sample stimuli in Condition 1, then 'old correct' and 'old opposite' were both reinforced in Condition 1 for the Response Prevention Group. When the data were interpreted in this way, there is evidence of resurgence of the old response by subjects in the Response Prevention Group but not in the Extinction Group. The extent of resurgence by subjects in the Response Prevention Group reduced over successive extinction trials. That is, the longer the subjects had been in Condition 2, the lower the probability that there would be a resurgence of responding consistent with Condition 1 contingencies when Condition 2 was disrupted.

Discussion

The present study trained pigeons in a matching-to-sample task with two conditions. In Condition 1, subjects were reinforced for making a particular response, while in Condition 2, subjects were reinforced for making a different response. Condition 2 responding was disrupted by three single extinction sessions which occurred at successive points during Condition 2. During the extinction sessions the response which had been reinforced in Condition 1 was available for all subjects to make. Resistance to change was measured as the persistence of responding consistent with Condition 2 contingencies, during extinction. Resurgence was measured as a shift back to responding consistent with Condition 1 contingencies when reinforcement was withheld in Condition 2.

In Group 1 (Extinction Group), responding consistent with Condition 1 contingencies was specifically extinguished in the process of reinforcing the 'new' response in Condition 2. This procedure investigated resistance to change and resurgence following extinction. In Group 2 (Response Prevention Group), the choice stimuli consistent with Condition 1 contingencies were not presented in the process of reinforcing the 'new' response in Condition 2. This meant that subjects in the Response Prevention Group were prevented from making a response consistent with Condition 1 contingencies. This procedure examined resistance to change and resurgence following response prevention.

Summary of Results

There was no evidence that a longer duration of Condition 2 reinforcement contingencies prior to disruption increased resistance to change. Subjects in the Extinction Group showed a slight decrease in the proportion of correct responses, relative to baseline, over successive extinction tests. Subjects in the Response Prevention Group showed no clear trend in correct responses over the three extinction tests.

The results of the present study indicated that responding by subjects in the Extinction Group was more resistant to disruption than responding by subjects in the Response Prevention Group. Relative to baseline, subjects in the Extinction Group had a greater proportion of correct responses (consistent with Condition 2 contingencies) during extinction, than did subjects in the Response Prevention Group.

The initial analysis of errors indicated that subjects in the Response Prevention Group showed evidence of resurgence of responding consistent with Condition 1 contingencies. While subjects in the Response Prevention Group made the three different errors at a similar level, all subjects in this group made 'old correct' errors at or above chance levels in Extinction tests 1 and 2. In the third extinction test, two of the four subjects in the Response Prevention Group showed a preference for this type of error. Subjects in the Extinction Group clearly favoured 'new opposite' type errors in each extinction test. Given that the extinction tests were the first opportunity that subjects in the Response Prevention Group had to make the previously-reinforced, the extent of the resurgence

was surprising. As such, an explanation for the small level of resurgence in this group was sought, and further analysis completed.

I have argued that in the Response Prevention Group there may have been a lack of stimulus control by the sample stimuli during Condition 1, and as such, the data treatment described above was not appropriate. For the Response Prevention Group in Condition 2, the same two choice stimuli were shown on each trial, meaning that the subjects had to learned to discriminate between the different sample stimuli in order to make a correct response. This was not the case in Condition 1. In Condition 1 the choice stimulus which was correct in the presence of one sample stimulus was never shown in the presence of the other sample stimulus. This meant that, to make a correct response, subjects in the Response Prevention Group simply had to peck the vertical line or square choice stimuli when they were shown.

When 'old correct' and 'old opposite' errors were both interpreted as previously-reinforced responses (i.e., 'combined old correct'), subjects in the Response Prevention Group showed a preference for this type of error over the 'new opposite' type. In contrast, the Extinction Group still showed a preference for the 'new opposite' type error when the data were analysed in this way.

The Response Prevention Group showed resurgence of a previously-reinforced response (whether defined either as 'old correct' or 'combined old correct') when reinforcement for a recently-reinforced response was withheld. For three out of the four subjects, this

resurgence reduced by the third extinction test. This indicated that the longer a new response had been reinforced, the less likely that an old response would resurge when the new response was challenged

Resistance to Change–Implications for Theory

The implications of the present study for resistance to change are discussed below in two sections; the first addresses the finding that resistance to change did not increase with an increased duration of Condition 2 reinforcement contingencies. I propose that this finding may be accounted for by a number of possible explanations, including the extent of the generality of Behavioural Momentum Theory. I also suggest that the experimental procedure used in the present study may have affected the within subjects measurement of resistance to change, due to the use of successive extinction, and the extent of the temporal separation between extinction tests.

The second section addresses the between groups difference in the level of resistance to change. I propose that while this difference indicates different levels of resistance to change between the two groups, this measurement may have been compromised by a discrimination problem caused by the experimental design. Furthermore, I suggest that the between groups measurement of resistance to change may have been confounded by different levels of disruptive force applied to the two experimental groups.

Duration of Reinforcement Contingencies

The results indicated that resistance to change did not increase as a function of the increase in duration of the Condition 2 reinforcement contingencies. There are a number of possible explanations for this finding. First, the duration of reinforcement contingencies may not be an appropriate extension of the 'generosity' principle of Behavioural Momentum Theory. Mace et al. (1990) argued that Behavioural Momentum Theory describes a general behavioural relation, whereby more generously reinforced behaviour is more resistant to disruption. The present study sought to extend this principle to include the duration for which a reinforcement contingency has been in place. The result of the present study did not support such a generalisation. While this finding might seem to weaken the generality of Behavioural Momentum Theory, a number of factors suggest otherwise.

As discussed above, many authors have found that frequency, magnitude, and immediacy of reinforcement increase resistance to change (eg. Nevin, 1979; Nevin et al., 1983). In the introduction to the present study it was suggested that the common element in these factors is the more generous reinforcement in the presence of a stimulus. The duration for which a reinforcement contingency had been in place seemed intuitively to also relate to the generosity of reinforcement. However, it could be argued that frequency, magnitude and immediacy all concern the maximization of reinforcers in a time period, which is in turn defined by the duration of reinforcement contingencies. Thus, an increase in the duration for which the contingencies have been in place is distinct from the 'density' of reinforcement within that contingency. It is possible that

rather than being inconsistent with Behavioural Momentum Theory, the results of the present study can be seen to clarify the meaning of 'generously reinforced'.

A second explanation for the findings of the present study relates to the experimental procedure used. It is possible that the measurement of resistance to change was affected by the use of successive extinction tests. It is conceivable that in the first session of extinction, subjects learned that once reinforcement for a response was withheld in a session, there was little point in making that response. If this were the case, any increase in resistance to change across extinction tests would be reduced by the effects of extinction learning.

Finally, the measurement of resistance to change across extinction tests may have been confounded by the extent of temporal separation between the tests. Cohen (1998) proposed that for behavioural momentum effects to be shown, it is necessary that the extent of temporal separation between the reinforcement schedules allow for a comparison to occur between the schedules. This enables differential responding to appear when both responses are challenged. While several studies have made use of a between groups and between-conditions comparison (e.g. Nevin, 1988), based on Cohen's (1998) research it is necessary that the temporal separation be 'within session' to enable a comparison to occur. Cohen's (1998) finding was supported by Grace and Nevin's (1999) research in which it was claimed that inter component intervals affect the ability to obtain resistance to change measures due to the extent of separation between the two components being measured.

In the present study, resistance to change was compared between extinction tests which were separated by up to twenty baseline sessions. It is unlikely that the extent of this temporal separation would have enabled the necessary comparison which would have allowed differential responding to appear. This limits the ability to measure resistance to change across extinction tests. The violation of this rule was also a factor in the problems associated with the between groups comparison of resistance to change described below.

Proportion of Correct Responding

Results indicated that there was a between groups difference in the persistence of correct responses (consistent with Condition 2 contingencies) during extinction tests. Subjects in the Extinction Group had a higher proportion of correct responses during extinction relative to baseline than did subjects in the Response Prevention Group. I have suggested that a greater proportion of correct responses during extinction indicates greater resistance to change. However, these results may have been affected by a difference in the level of conditional discrimination between the two groups.

In the extinction tests, subjects were presented with the choice stimuli from both Conditions 1 and 2. In Condition 1, subjects in the Response Prevention Group did not need to learn to discriminate between the sample stimuli in order to make a correct response. This meant that 'old correct' and 'old opposite' errors could both be interpreted as previously-reinforced responses regardless of the sample stimulus presented. This argument is consistent with Figure 8 which showed that for three out of

four subjects in the Response Prevention Group 'old correct' and 'old opposite' errors occurred at a similar level. Because responses consistent with Condition 1 contingencies had never been specifically extinguished, their extinction sessions therefore contained three (out of four) choice stimuli that were associated with reinforcement. This would mean that 'correct' responses during extinction (in which three out of the four possible responses had been associated with reinforcement) were being expressed relative to baseline (in which one out of only two possible responses had been associated with reinforcement). This would create an impression of lower resistance to change when the test data were analysed. Moreover, this conditional discrimination problem only applies to the Response Prevention Group, hence it may produce a difference between the two groups.

A further related problem in the comparison of resistance to change between the Extinction and Response Prevention Groups was a potential difference in the level of force applied during disruption. For the effective measurement of resistance to change it is necessary that any disrupter is applied equally to both responses (Harper 1996). This was not the case in the present study, in which it could be argued that there was a difference between the two groups in the extent of the change in stimulus situation during extinction. Specifically, the extinction tests, there was a greater change in stimulus situation for the Response Prevention Group than for the Extinction Group. For subjects in the Response Prevention Group, baseline training in Condition 2 involved the presentation of a sample stimulus followed by two choice stimuli. In the extinction tests, subjects in this group were shown three choice stimuli, including those

that had previously been shown in Condition 1. Therefore, subjects in the Response Prevention Group had a large change in stimulus situation during extinction. In contrast, subjects in the Extinction Group were shown three choice stimuli throughout baseline training in Condition 2. This meant that subjects in the Extinction Group had the same stimulus situation during the extinction tests as during Condition 2, except for the absence of reinforcers. The difference between the two groups in the extent to which the stimulus situation changed during extinction may have acted to compromise the between-groups measurement of resistance to change. Thus, while the Extinction Group and the Response Prevention Group both experienced the same extinction test conditions, there was a difference between the two groups in the number of choice stimuli used during baseline, and association of reinforcement to these stimuli. These differences may have meant that the extinction tests results in the two groups were not comparable.

Summary of Resistance to Change.

The contribution of the present study to the resistance to change literature is complicated by the uncertainty regarding the type of design used to measure resistance to change. Results indicated that resistance to change did not increase with an increased duration of reinforcement contingencies prior to disruption. While this finding can be accommodated by Behavioural Momentum Theory, there were also a number of potential problems with the within-subjects measurement of resistance to change.

The result of the present study suggested that there was a between-groups difference in the level of correct responding, in that, the Extinction Group maintained a higher

proportion of correct responses relative to baseline that the Response Prevention Group. However, for the Response Prevention Group, this measure may have been confounded by a conditional discrimination problem in extinction. Furthermore, due to procedural differences, it was possible that the disruptive force applied to the Response Prevention Group was greater than that of the Extinction Group. Finally, it should be noted that, while these procedural differences may have influenced the measurement of resistance to change, this is unlikely to be the case in the analysis of resurgence. Data relating to resurgence, described below, measure type of error as a proportion of total errors, removing the potential complication of a measurement of overall error rate.

Resurgence-Implications for Theory

Having dealt with the disruption of matching-to-sample performance during extinction, implications regarding the types of errors made during disruption will now be discussed. In the present study, the Response Prevention Group showed resurgence of 'correct' and 'combined old correct' when Condition 2 was disrupted with extinction. The Extinction Group did not. This suggests that resurgence is more likely to occur following disruption of a new response, if the old response has been prevented from occurring in the process of reinforcing the new response.

Figure 8 indicated that 'new opposite' type errors also occurred at a relatively high level for subjects in the Response Prevention Group. The occurrence of a 'new opposite' type response may be accounted for by the subjects still being in the process of learning to discriminate between the two sample stimuli in Condition 2. Figure 4 showed that prior

to the first extinction test, subjects in the Response Prevention Group were making a correct response on 72 % of trials. This meant that these subjects were making 'new opposite' type errors on 28 % of trials during baseline.

During the extinction tests, 'correct' and 'new opposite' type responses accounted for 48% % of total responses averaged for all subjects in the Response Prevention Group, and of those, 58 % were correct responses. This meant that during extinction, on average, subjects in the Response Prevention Group made either a 'correct' or 'new opposite' response on approximately half of all trials. Of these responses, subjects in the Response Prevention Group showed a preference for 'correct' over 'new opposite', that was roughly comparable with baseline levels of accuracy.

In contrast to the Response Prevention Group, the Extinction Group clearly favoured the 'new opposite' type error when Condition 2 was disrupted. A comparison of the types of errors made by subjects in the Extinction Group during Condition 1 (Figure 1) and the types of errors made during the three extinction tests (Figure 10) indicated that the Extinction Group made a similar type of error in both cases. While the proportion of 'new opposite' errors compared to the other errors was slightly reduced during the extinction tests, it was still very high for all Extinction Group subjects. Thus, for subjects in the Extinction Group, the history of reinforcement in Condition 1 appeared to have little influence on the type of responding in the extinction tests in Condition 2. While it is not possible to compare Condition 1 errors with extinction errors for the Response Prevention Group (there was only one possible error in Condition 1), there is

clearly a difference in the errors made during extinction between the two groups. This indicates that the extinction of responding consistent with Condition 1 contingencies was effective in reducing the likelihood of the response recurring after Condition 2 training.

The lack of resurgence in the Extinction Group is consistent with research by Wilson and Hayes (1996), described earlier, which used human subjects. Wilson and Hayes (1996) found that resurgence only occurred in extinction if responding consistent with the new response was specifically punished. In the present research, responding consistent with Condition 2 contingencies was never specifically punished. To that extent the results of the present study supported the lack of resurgence found by Wilson and Hayes (1996) prior to punishment of the new response.

Mechanisms of Resurgence

As stated in the introduction to this research, there has been relatively little research conducted on resurgence. Most theory around the phenomenon relates to possible mechanisms underlying resurgence. The results of the present study support the response prevention hypothesis of resurgence over the discriminative cues hypothesis. The discriminative cues hypothesis postulates that the simultaneous extinction of the original response and the introduction of reinforcement for an alternative response creates a discriminative cue. When reinforcement for the alternative response is withheld, the experimental conditions return to something that resembles the original training context. This, in turn, causes the original response to recur (Rawson et al., 1977).

Applied to the present study, the discriminative cues hypothesis predicts that the Extinction Group should show resurgence of the previously-reinforced response during extinction of the new response, while the Response Prevention Group should not. To explain, in Condition 1 the Extinction Group subjects were reinforced for making one response and not reinforced for making another. In Condition 2, this original response was extinguished and an alternative response was reinforced. During the probe extinction tests, reinforcement for this alternative response was removed, potentially creating a context which, to some extent, resembled the original context. This meant that for the Extinction Group, the only difference between Condition 1, Condition 2, and the extinction tests, was the presence or absence of reinforcement for original or alternative responses.

In contrast, for the Response Prevention Group, the context in the extinction tests did not resemble Condition 1 or Condition 2. During the extinction tests all three keys were illuminated with choice stimuli. Choice stimuli which were correct for Condition 1 and Condition 2 were potentially present at the same time. For subjects in the Response Prevention Group this context was novel and did not resemble the original context. Thus, if the discriminative cue hypothesis was correct, the Extinction Group should have shown resurgence and the Response Prevention Group should not. The results of the present research indicated that the Response Prevention Group showed resurgence of responding consistent with Condition 1 contingencies, while the Extinction Group did not. Thus, the results of the current research do not support the 'discriminative cue' hypothesis of resurgence.

The response prevention hypothesis suggests that the introduction of reinforcement for an alternative response prevents the subject from fully experiencing the extinction of the old response. This means that when reinforcement for the alternative response is removed, there is a resurgence of the original response which is now available again (Rawson et al., 1977). Applying this reasoning to the Extinction Group in the present study, these subjects were prevented from fully experiencing the extinction of the old response due to a shift in responding to the new response. However, it should be noted that subjects had to experience some extinction of the previously-reinforced response in order for this shift to occur. In contrast, the Response Prevention Group were specifically prevented from making the previously-reinforced response when learning the new response. Therefore, this group had no experience of extinction of the previously-reinforced response. This was true response prevention. The response prevention hypothesis predicts that both groups should have shown resurgence of the previously-reinforced response when reinforcement for the new response was withheld (Rawson et al., 1977). However, resurgence should have been greater in the Response Prevention Group, who had no experience of extinction, than in the Extinction Group, who had experienced partial extinction of the old response.

While the Response Prevention Group showed resurgence of 'old correct' and 'combined old correct' responses, the Extinction Group did not. Thus, the results of the present study would seem to only partially support the response prevention hypothesis. This finding is inconsistent with Rawson et al. (1977) who found that response prevention, and extinction with reinforcement for an alternative response resulted in a

similar level of resurgence when reinforcement of the new response was withheld. However, the Extinction Group in the present study differed from that of Rawson et al. (1977) in the duration of conditions and the complexity of the task.

Rawson et al.(1977) trained rats to press a lever on a continuos reinforcement schedule. The training of the original response (pressing Lever A) consisted of five 30-minute sessions. Similarly, reinforcement for an alternative response (whether through extinction or response prevention) also consisted for five 30 minute sessions. In contrast, the Extinction Group of the present study responded in a relatively complex matching-to-sample task. Training in Condition 1 consisted of an average of 100.25 sessions, while the average number of sessions in Condition 2 prior to the first extinction test was 20.25. It is conceivable that length of Condition 1 meant that the original response was relatively strong.

Visual inspection of Figure 2 indicates that after five sessions in Condition 2 (the number of sessions of alternative response training used by Rawson et al. (1977)) the average proportion of correct responses by subjects in the Extinction Group was at chance levels (0.32). The occurrence of the 'correct' response at chance level after five sessions in Condition 2 indicates that it took longer for subjects in the present study, compared to Rawson et al. (1977), to shift their responding to the alternative response. Furthermore, subjects had the opportunity to continue to make the old response on some trials during Condition 2. This would mean that by the first extinction test, responding

consistent with Condition 1 contingencies had been more completely extinguished than for Rawson et al.'s (1977) subjects. Given that subjects in the Extinction Group were forced to experience the extinction to Condition 1 contingencies, the absence of resurgence is not necessarily inconsistent with the response prevention hypothesis.

Summary of Resurgence

Results demonstrated that when Condition 2 responding was disrupted with extinction, subjects in the Response Prevention Group showed a resurgence of responding consistent with Condition 1 contingencies ('old correct' and 'combined old correct'). Furthermore, resurgence reduced over successive extinction tests. This indicates that the longer reinforcement contingencies are in effect prior to disruption, the less likely that a previously-reinforced response will increase when the recently-reinforced response decreases. Subjects in the Extinction Group did not show resurgence of the previously-reinforced response, favouring instead, 'new opposite' type errors when Condition 2 contingencies were disrupted. As discussed above, there are a number of reasons why the Extinction Group may have experienced full extinction of the previously-reinforced response. Thus, the results of the present study are consistent with the response prevention hypothesis of resurgence. It is suggested that reinforcement for an alternative response only acts to prevent the full experience of extinction of an old response, if the shift in responding occurs soon after the introduction of extinction of the old response. Factors which may prevent a fast shift from the old response to an alternative response may be the duration of reinforcement for the old response, and the complexity of the task.

Implications for Relapse

In the introduction to this research it was suggested that relapse is a behaviour which may be understood in terms of behavioural principles. Relapse occurs when a recently-reinforced behaviour (Behaviour 'B') is challenged in some way, decreases in probability, and the subject reverts back to an old previously-reinforced behaviour (Behaviour 'A'). I have taken the view that literature which deals with resistance to change and resurgence is relevant in examining relapse behaviour. Resistance to change describes how likely a response is to withstand disruption. Resurgence describes what responses increase when a disrupted response decreases. In the present study, a higher level of correct responses (as defined by Condition 2 contingencies) was taken as indicating greater resistance to change. In turn, greater resistance to change indicated a reduced likelihood for relapse. Resurgence was defined by an increase in 'combined old correct' during the extinction tests in Condition 2.

Results of the present study showed that the Extinction Group had a greater proportion of correct responding during extinction, relative to baseline, than subjects in the Response Prevention Group. It has been suggested that this difference could be accounted for by different levels of conditional discrimination in the two groups. This between groups measure may have been confounded by unequal force applied to the Extinction and Response Prevention Groups. Given these considerations it is difficult to apply these findings to the relapse paradigm. While the results of the of the present study suggest that the recently-reinforced response persisted at a higher level during

disruption when the previously-reinforced response had been specifically extinguished, this finding must be qualified by the measurement problems described above.

Similarly, results demonstrated that a previously-reinforced response was less likely to resurge following disruption of a recently-reinforced response, if the previously-reinforced response had been specifically extinguished. The longer a new response had been reinforced prior to disruption, the less likely it was that the previously-reinforced response would resurge when the new response was disrupted.

Applied to the relapse scenario presented above, the results of the present study suggest that if Behaviour 'A' is specifically extinguished in the process of reinforcing Behaviour 'B', then when Behaviour 'B' is disrupted, it may be more persistent than if the Behaviour 'A' was simply prevented from occurring. Similarly, when Behaviour 'B' does reduce with disruption, it is less likely that the subject will relapse back to previously-reinforced Behaviour 'A' if it was specifically extinguished previously. The probability of relapse under these conditions is likely to be reduced the longer Behaviour 'B' has been reinforced prior to disruption. If the previously-reinforced Behaviour 'A' is extinguished in the process of reinforcing Behaviour 'B', then a reduction of Behaviour 'B' with disruption is more likely to result in an increase in other recently-reinforced behaviours.

The current study offers practical possibilities in the study of relapse in human subjects. While the term relapse is often associated with addictive behaviours, I have taken the

view that relapse can be seen as a general behavioral response. For example, in their study of the psychological antecedents of criminal recidivism, Zamble and Quinsey (1997) suggested that criminal recidivism can be seen as a relapse behaviour. In recidivism, the offender relapses back to old habitual behaviour patterns which lead to criminal activity (Zamble & Quinsey, 1997). Andrews and Bonta (1998) illustrated the influence that learning has on criminal behaviour in their 'personal, interpersonal and community-reinforcement (PIC-R)' perspective on criminal behaviour. Similar to the view taken in the present research, they suggested that the occurrence of behaviour (whether criminal or legal) is controlled by the presence of antecedents and consequences (Andrews & Bonta, 1998).

Zamble and Quinsey (1997) proposed that most offenders end a prison sentence intending to avoid re-offending, and do attempt to change their lives. The path toward crime-relapse begins when the individual is presented with a problem, or external challenge. These external challenges draw on the individuals' coping behaviours. Among their response choices the individual has both the responses which they have learned to deal with situations effectively, and a number of practiced or habitual types of antisocial responses. In a challenging situation, the choice of behaviour depends, in part, on the relative availability of these behaviours in a person's repertoire (Zamble & Quinsey, 1997).

There are clear parallels between Zamble and Quinsey's (1997) description of the process toward criminal recidivism and the behavioural model of relapse which I have

proposed. In the present study, responding in Condition 2 was challenged by the withdrawal of reinforcement during the extinction tests. During this challenge, among their response choices, subjects had both the recently–reinforced response consistent with Condition 2 contingencies, as well as the previously-reinforced response consistent with Condition 1 contingencies. Similar to Zamble and Quinsey's (1997) description, the responses which subjects in the present study made was affected by the availability of these behaviours, due to prior extinction or response prevention.

Thus, when the present study is viewed as a simplified model of relapse in humans, it has implications for the prevention of relapse in humans. Take the example of an individual who is habitually aggressive and violent. This may be viewed as a learned behaviour in the presence of a particular stimulus; the stimulus of stress results in the behaviour of violence. This represents undesirable Behaviour 'A'. If this individual sought treatment and was taught certain stress management techniques, the use of those techniques when stressed is desirable Behaviour 'B'. The extinction (or other disruption) procedure may be likened to an environment in which social approval is withheld for the display of these stress management techniques. For example, Andrew and Bonta (1998) argued that one of the risk factors for criminal behaviour is criminal associates. In an antisocial peer group it may be seen as acceptable to physically assault one's partner (in which case pro-social behaviour may be disapproved of or 'punished'), or the environment may simply fail to actively reinforce pro-social stress management techniques (extinction).

While the example of antisocial associates given above can be likened to extinction of reinforcement for Behaviour 'B', in an uncontrolled setting it is impossible to ensure total withdrawal of reinforcement. However, resistance to change research indicates that there are a large number of factors that can disrupt behaviour and lead to predictable changes (Nevin & Grace, 2000). For example, pharmacological agents have been shown to disrupt responding in animal subjects (Harper, 1999a, 1999b). It is possible that in the hypothetical scenario presented above, Behaviour 'B' could be disrupted by the consumption of drugs or alcohol. Similarly there are a number of factors which, without being pure extinction, may act to reduce reinforcement for Behaviour 'B'. For example, Andrews and Bonta (1998) have found that employment is associated with an increase in the frequency of reinforcement for pro-social, non-abusive behaviours. This suggests that the loss of employment may challenge Behaviour 'B' through the reduction of reinforcement. This illustration demonstrates the way in which behavioural principles can be mapped on to complex human behaviours.

The present study has compared two ways in which reinforcement for an old response can be withheld in the process of reinforcing a new response, that is extinction and response prevention. As stated above, in an applied setting it is almost impossible to achieve total extinction for a previously-reinforced response. However, it could be argued that extinction is an example of a procedure in which the reinforcement structure shifts away from old Behaviour 'B', toward new Behaviour 'A'.

The way in which treatment interventions are delivered may impact on whether or when relapse occurs. For example, the individual described above may attend a residential treatment clinic in which the individual is taught and reinforced for Behaviour 'B'. However, in this environment the individual is not in a situation in which they are able to emit old Behaviour 'A'. Thus, this type of treatment programme may be viewed as response prevention (analogous to the Response Prevention Group in the present study). In contrast, this same individual may undertake a treatment intervention which is based in the community. The individual may attend a course during the day in which they are taught and reinforced for new Behaviour 'B'. Similarly the individual may receive further reinforcement for practicing this new behaviour in the home environment. However, in this intervention, the individual is still able to emit Behaviour 'A', but reinforcement has shifted to Behaviour 'B'. For example, the individual's partner will now call the police if the individual threatens them or becomes aggressive, the individual may call a support line if they believe that they are likely to emit Behaviour 'A', or the social approval of the treatment group may be removed.

The results of the present study indicated that, all other things being equal, if the subject is treated in a context in which the old response continues to be possible (but reward structures shift behaviour away from the old response), it is less likely that the subject would relapse to Behaviour 'A' when Behaviour 'B' is disrupted. Similarly, the longer the period of reinforcement for new Behaviour 'B' prior to disruption, the less likely that the individual will relapse to Behaviour 'A'. Finally, when Behaviour 'B' is disrupted, it is more likely that the individual will show an increase in other newly learned

behaviours, if the subject has experienced the withdrawal of reinforcement for emitting Behaviour 'A'.

Future Directions

Due to the innovative nature of the present study, there are a number of questions left unanswered, and future direction may first require a number of steps back. For example, it is unclear whether the matching-to-sample task used in the current experiment was appropriate for the measurement resistance to change. In the present experiment, the matching-to-sample procedure was used to measure resistance to change with increased duration of the reinforcement contingency prior to disruption. The duration of reinforcement contingencies is not a factor which has been researched before. Due to a number of problems in the measurement of resistance to change in the Response Prevention Group, it remains unclear whether contingency duration has an influence on resistance to change.

The uncertainty surrounding this result could be clarified in two ways. First, the effect of the duration of reinforcement contingencies prior to disruption could be tested using the standard free operant multiple VI VI concurrent schedule design. Second, the usefulness of the matching-to-sample task procedure in measuring resistance to change could be evaluated with two responses which are reinforced with different sized reinforcers. Responding could then be disrupted by a recognised disrupter, allowing the persistence of responding to be compared within subjects.

A second useful line of enquiry concerns the effects of punishment of a recently-reinforced response on resurgence. In their study using human subjects, Wilson and Hayes (1996) found that for resurgence of a previously-reinforced response to occur following extinction of a newly-reinforced response, the specific punishment of the new response was required. In the present study, the Extinction Group showed no resurgence of old responding during extinction. Wilson and Hayes' (1996) study suggests that if, in the present study, the new response had been punished during extinction, this may have resulted in a resurgence of responding consistent with Condition 1 contingencies. It would be relatively simple to test the effects of punishing the recently-reinforced response in an experimental design similar to that of the present study.

The effect of punishment of a newly-reinforced behaviour is of direct interest in a relapse situation. In the hypothetical example above using Behaviours 'A' and 'B', it was suggested that extinction could be likened to an environment in which social approval is withheld for the display of these stress management techniques. However, in a number of environments that an individual may return to following treatment, pro-social behaviours may be actively punished. Thus, the effects of this punishment on resurgence are of interest in the field of behaviour modification.

It has been suggested above that the true extinction of a previously-reinforced response is difficult to achieve in an applied setting. Hence, it would be of considerable interest to investigate the effects of other manipulations on resurgence. In the introduction to the present study it was suggested that resistance to change and resurgence are related. In a

resistance to change context, there are a number of manipulations which have been shown to disrupt responding. It is proposed that the examination of the effect of these disrupters on resurgence, as studied in the traditional multiple VI VI conditions, may elucidate the mechanisms which underlie resurgence, and support the connection between resurgence and resistance to change. Furthermore, were resurgence shown to occur with more diverse types of manipulation, this would strengthen the connection proposed in the present study, between resurgence and human relapse.

Finally, I have argued that it is difficult to determine if the difference between the persistence of Condition 2 responding in the Extinction and Response Prevention Groups was the result of a difference in resistance to change, or merely due to a poor conditional discrimination by subjects in the Response Prevention Group during extinction. While the introduction of more choice stimuli would be likely to cause its own problems, it would be of interest to see if subjects in the Response Prevention Group still distributed their responses evenly if they had a history of seeing three choice stimuli throughout Conditions 1 and 2. A control group could be added to the present experimental design in which response prevention was used, as well as presentation of stimuli on all three keys during Conditions 1 and 2.

Summary

The present study has defined the behaviour of relapse in terms of behavioural principles. I have suggested that research relating to resistance to change and resurgence is relevant to relapse behaviour. The present study attempted to use a matching-to-

sample task to measure resistance to change and resurgence concurrently. It was hypothesized that the longer Condition 2 had been in place, the more resistant responding would be to disruption. The results of the present study did not support this hypothesis. However, due to the original nature of the research design used, it is unclear whether this finding was affected by the procedure used. Similarly, it is not certain if the measurement of resistance to change as persistence of correct responding during extinction relative to baseline was confounded by a conditional discrimination problem.

It was hypothesised that the Extinction Group and the Response Prevention Group would show similar resurgence of an old response during disruption of a new response. However, subjects in the Response Prevention Group showed resurgence of responding consistent with Condition 1 contingencies, while the Extinction Group did not. It was argued that this finding was consistent with the response prevention hypotheses of resurgence, as subjects in the Extinction Group were likely to have experienced the complete extinction of the response consistent with Condition 1 contingencies. The resurgence shown by subjects in the Response Prevention Group reduced over successive extinction tests.

The findings of the present study were discussed in relation to their implications for relapse behaviour. It has been suggested that to decrease the likelihood of relapse to Behaviour 'A' it is important that reinforcement shifts away from Behaviour 'A' when Behaviour 'B' is being reinforced. Moreover, the likelihood of relapse is reduced the longer Behaviour 'B' has been reinforced for prior to disruption.

The present study offers many possibilities in the study of relapse behaviour. Through building a model of relapse in an experimental analysis of behaviour setting, it is possible to isolate factors influencing responding. While human behaviour is not determined solely by its relationship to environmental antecedents and consequences, these are key factors. Furthermore, the antecedents and consequences of behaviour are measurable and adaptable. Thus, the study of how these factors interact to influence responding offers practical possibilities in behaviour modification.

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